Roskilde University

The methods and subject matter of physics

an introduction to pedestriants (but not excluding cyclists). part I: physics in society

Sørensen, Bent

Publication date:
2001

Document Version
Peer reviewed version

Citation for published version (APA):
Sørensen, B. (2001). *The methods and subject matter of physics: an introduction to pedestriants (but not excluding cyclists). part I: physics in society*. Roskilde Universitet. Tekster fra IMFUFA No. 129bis

TEKST NR 129bis 2001

Bent Sørensen

PHYSICS REVEALED

THE METHODS AND SUBJECT MATTER OF PHYSICS

an introduction to pedestrians
(but not excluding cyclists)

PART I: PHYSICS IN SOCIETY

JANUARY 2001

TEKSTER IMFUFA

fra Institut 2

ROSKILDE UNIVERSITETSCENTER
INSTITUT FOR STUDIET AF MATEMATIK OG FYSIK SAMT DERES FUNKTIONER I UNDERVISNING, FORSKNING OG ANVENDELSER

ROSKILDE UNIVERSITY, P O BOX 260, DK-4000 ROSKILDE, DENMARK
INSTITUTE OF STUDIES IN MATHEMATICS AND PHYSICS, AND THEIR FUNCTIONS IN EDUCATION, RESEARCH AND APPLICATIONS
TEL: +45 4674 2000, FAX: +45 4674 3020, WEBSITE: http://mmf.ruc.dk/energy

JANUARY 2001
PHYSICS REVEALED: The methods and subject matter of physics, an introduction to pedestrians (but not excluding cyclists). PART I: PHYSICS IN SOCIETY

this text may be downloaded from http://mmf.ruc.dk/~boson/fysikE

printing history:
-as lectures notes, 1983
-reprinted as IMFUFA Text 129, 1986
-published in part in *Modernitet: differentiering og rasjonalisering (H. Grimen, Senter for Vitskapsteori, Bergen Universitet, ed.)* som *Reflektioner over vort had/kærlighedsforhold til teknologi og videnskab*, pp. 3-43. Ariadne Forlag, Bergen 1990
-this version: part 1 of the material for the course FYSIK E, spring 2001

IMFUFA text 129bis, 72 pages ISSN 0106 6242

Abstract:

This is part 1 of 3, serving as reading material for the a course called Physics E. The course addresses students not aiming at becoming physicists (although some do after all!), as part of the two-year curriculum for the Natural Science base years of the Bachelor and Master's studies at Roskilde University.

Adjoining materials:
Part 2: Physics proper, deals with the subject matter of physics
Part 3: Physics in a philosophical context, deals with the philosophy of science, and the history and future of physics

Contents of Part I:

Bent Sørensen

PHYSICS REVEALED

THE METHODS AND SUBJECT MATTER OF PHYSICS

an introduction to pedestrians
(but not excluding cyclists)

PART I: PHYSICS IN SOCIETY

JANUARY 2001

PREFACE

This material grew out of a series of lectures held at Roskilde University since 1982. It has been somewhat updated for the 2001 lectures, but many of the issues used to illustrate physics are unchanged from the 1983 version, reflecting a belief that the most recent illustrations are not always the most instructive ones.

The course using this material is primarily aimed at first (two) year's natural science students not aiming at specialising in physics (although some do after all). It is, however, very different from the available textbooks for such courses, which generally try to make these people "small" ordinary physicists by presenting them a simplified version of "real" physics textbooks.

My treatment does not present a simplified version of physics. All the complexity is there, but it is not what the student is supposed to master. The student has achieved the purpose of the course if he or she at the end knows the breathtaking depth of the subject matter of physics and has a feeling for the kind of methods employed by physicists. In addition to this, the position of science in current society is presented for debate, and is placed in a historical and philosophical context.

Dyson once said: The difference between a text without problems and a text with problems is like the difference between learning to read a language and learning to speak it (Dyson, 1981). I shall invite the reader to join in two kinds of exercises. One I call "problems" and the other "discussion issues". Both are found at the end of each chapter. The problems may be solved using physical theory at some level. Some may be answered from everyday experience, but in such cases a physical reasoning should be sought. In many of the problems, the sharpening of the formulation into a welldefined set of questions is 90% of the solution. Such detailed formulations will be given for selected problems, but remember that it is only in textbooks that these precise problem formulations exist. In real life, problems are mostly diffuse and open-ended. Here is one to start you off: Read the short love story from my book *Superstrings*, which you can find on my web page http://home9.inet.tele.dk/novator/Bent/SSTkap45.htm and discuss what it has to do with relativity theory [at the moment, the story is only in Danish].

The other participation part consists of bringing up society-related issues connected to the text in each chapter. They may be discussed in groups or with yourself as the discussion partner. They may lead you anywhere, and there are no correct or false conclusions. I hope the reader will think of further discussion topics. People insisting that they see no problem in entrusting quantitative evaluations of scientific issues to politicians or some other decision-makers may of course skip these problems!

Gilleleje 2001, Bent Sørensen

PHYSICS REVEALED: The methods and subject matter of physics, an introduction to pedestrians (but not excluding cyclists).

CONTENTS

Contents of Part I (physics in society):
[This volume: IMFUFA Text 129bis]

Contents of Part II (physics proper):
[available as IMFUFA Text March 2001]

Contents of Part III (physics in philosophical context):
[IMFUFA Text 392, in Danish only]

CHAPTER 1
INTRODUCTION TO PHYSICS

Physics is a discipline created in an attempt to understand our surroundings, near and distant, small and big. To do so, it uses models. Most are simplified, most are mathematical models. But they are not the *ad hoc* models used in social sciences. They have to stand the test of experimental verification, which despite obvious dangers of error does emphasise objectivity. Physics is based on the principle of objectivity (i.e. independence of the views of particular investigators), but also aims at defining limits for each theory, inside which questions have answers, but generally not outside these limits. Many theories are deliberately simplifying things by idealised assumptions. They are valid if the assumptions are valid, and may describe reality only to the extent reality is kind enough to obey the assumptions. Even when answers are not unique, as in certain parts of quantum theory, there are precise formulations on when one can answer a question unambiguously and when not. To understand the precise meaning of these statements is to understand the nature of physics, and it is the subject of the following chapters, whether on the subject matter of physics or on its basic philosophy or its interpretation in society.

To get started, let me quote some interview studies on the nature of physics. Among the replies to "what is physics" the following categories of answers were given:

PHYSICS IS:

* too difficult compared with its usefulness
* just one of many interesting subjects
* bloody exciting
* boring
* dull
* important for understanding many things in public debate
* of no consequence for me personally.

These selected answers were received from a questionaire given to students at the beginning of a "physics in society" course, with the purpose of looking at preconceptions of the subject. Here follows another group of answers to the "what is physics" question:

PHYSICS IS:

* what the physicists do at universities, research laboratories and so on
* knowledge about dead nature, just as biology is knowledge about living nature
* what is in the physics textbooks
* theories about interconnections in nature
* a collection of methods aimed at structured investigation of our surroundings.

Most of these were not spontaneous formulations, but a series of suggestions by the teacher, to which the student could "agree" or "disagree".

The "what is physics" question does have several sides to it. Below is a third set of answers.

PHYSICS IS:

* like art, a part of our culture

* the basis of technological progress

* power!

* an instrument for putting people into boxes, just like Latin in the old days - one box for those who can, and one for those who can't. Those in the second box should not count on being heard in questions of important decisions in society - they are outside, they are out....

Now what do we do with all these bids on the nature of physics? The first group of answers relates to the reaction of the individual towards physics as a topic - and in particular physics as a school topic. The second group of answers tries to characterise the "internal nature" of physics, that is to describe its subject matter, its substance and its methods. The third group of answers attempts to characterise physics "from the outside", by describing its applications and status in society.

All the groups of answers represent legitimate interests

- those of the individual and those of the society. The descriptions of physics are either abstract or they are user-oriented, they are aimed at the contents or at the functions of physics in a particular society.

What is physics to the physicist? Many physicists have in fact made statements on what they think physics is, so let me quote a few examples.

A Danish physics professor named Ellinger started his popular physics book published in 1897, with the following statement (Ellinger, 1897):

"Man is a born explorer of nature". After explaining how man - in contrast to other animals - is poorly equipped for survival and therefore has to understand nature and its forces in order to be able to exploit them. Ellinger goes on to define physics. Physics is a method for looking at our surroundings, for distinguishing the important things from the unimportant ones, for seeing the connection between complex phenomena, and in particular for deciding what is cause and what is effect. Physics seeks a relationship between things, it seeks truth and nothing but truth. The physicist learns about nature in two ways: By observing what goes on in nature without interfering, and by setting up specific experiments.

Apart from Ellingers lack of appreciation of Darwin's evolution theory, he clearly could have agreed with most of the formulations in the second batch of "what is physics" answers in the student questionaire. Also, his emphasis on the importance of experimentation in physics would be echoed by most contemporary physicists. More problematic is the kind of approach suggested, consisting in part in just observing what goes on around us. How are we to know what to look for? There is an infinite amount of potential information around us, so we have to start with an idea of what we are looking for. In essence we must have at least a rudimentary theory before we can meaningfully begin observations. If I shouted "look!", would you look out through the window, would you look at me, or would you perhaps start searching for tiny objects on the floor? Probably I would only manage to confuse you. It is no help to be told to "look", if one does not have an idea of what to look for.

Let me now turn to more contemporary attempts at defining physics. In 1972, the United States National Academy of Sciences (NAS) tried to describe physics in a series of books called "Physics in Perspective" (National Academy of Sciences, 1972). It was at the time when funds for physics research had started to flow less automatically than during the post-war boom, and the physicists hoped that if they argued their case better, they might still retain their place at the top of fiscal budgets. NAS defines the nature of physics in these words:

Science is knowing, and what man knows about inanimate nature is physics. More specifically, physics is composed of the most lasting and universal such knowledge. It is the purpose of physical science to formulate universal laws. Physics has brought not only insights but also power. NAS finds it more debatable, whether or not physics has an intrinsic value - if physics is culture - and whether it always has practical applications or not. Must the physicist justify her/his work (and its funding) by relating/it to applications, say for technology or for finding solutions to pressing social problems?

Going back to a discussion of the boundaries of physics as a subject, the National Academy of Sciences notes that physics is concerned with questions that cannot be decided by thought alone. Ideas must be tested by experiments. However, experimental discovery often generates new questions, and thereby creates a fruitful! Interaction between theory and experiment, in which new theories are not pulled out of a vacuum. Yet the particular path leading to the formulation of a theory and the experiments that support it should not affect the objectivity of the results: There is every reason to believe that the answers, once found, have a permanent and universal validity.

The National Academy is much more cautious than Ellinger in assigning a cultural value to physics, and it also wants to play down the notion of a direct coupling between physics (notably its level of funding) and the amount of technological or other application derived from it. However, NAS shares Ellinger's view of physics as knowledge and as objective truth. While Ellinger only seems to see this knowledge as a tool for exploiting nature, the National Academy uses the word "power", implying a possibility of exploiting not only nature, but also people. Physics is knowledge, and as long as others do not possess that knowledge, it is power. The alternative of sharing the knowledge is not mentioned by the National Academy of Sciences, but more on this later.

The two examples above already give an impression of most of the views of physics, which are expressed by physicists. A pure "physics is culture" view is expressed by Feynman (Feynman, 1973). He finds physics, like music and dance, useful and very entertaining to a human being. That is why he has chosen to study physics. The direction of physics is largely determined by the funding given to it. Whether or not money should be given to physics research, rather than say to eradicating poverty in the United States, is a political problem that Feynman does not feel qualified to answer. However, he does think it less effective to disperse funds over many items rather than spending them on one. Technological application is a bad argument for funding specific physics research, because some of the physics that is most fun is also most remote from applications. Unlike Ellinger who wanted to understand nature. Feynman looks at his contribution to physical theory in the following way: "I don't explain anything, I just tell you how it works".

Most scientists would agree with Feynman: Research is fun! However, the majority of active scientists today have been in the privileged situation of being able to choose to study a science, due to the social position of their families or because they had exceptional qualifications and these were discovered by people of sufficient influence. Therefore, a scientist may not be the best person to ask questions about the way in which science functions in society.

Quite a different look at these issues came up during the Cultural Revolution in China. It quickly identified the social status of many scientists as preventing them from evaluating the role of their work in the framework of majority views in society. And in consequence, the scientists were plainly deprived of any influence *on* the conduction of their discipline. Instead, "the people" took" over control. This era in Chinese history gives us an idea of what popular views on the role of science were in China at the time. Scientists were considered to live in an ivory tower and to believe, that they were outstanding from the masses. As there was probably a good deal of truth in this, one may find it understandable that Cai Zu-quan wrote in the Chinese Journal of Physics (Cai, 1974), that the wise guys are really stupid, while the men and women on the floor are the wisest and most talented in the world. The "bottom" people create the material and spiritual wealth, and only they have a practical experience with things. This leads Cai to define physics as technology and only technology. The ordinary people decide what technology they want, and then the physicists and other scientists have to provide it. Thus the true scientists are the technicians (such as Cai, presumably) who knows how to manufacture things. As an example. Cai's team produced a mercury lamp, succeeding despite the fact that they had never previously made such lamps!

The description of Cai's mercury lamp takes only a few lines of the article, which is otherwise a four letter word attack on the Chinese upper class and Lin Piao in particular. The interesting part is of course, that the "Great Proletariat" held the Journal of Physics in such high esteem, that they found it worth the trouble to take it over and to publish political rubbish in it, using the format of traditional scientific articles. As for the identification of physics with technology, Cai seems to forget that the entire notion of a mercury lamp and its way of functioning had to be there in advance. The practical experience of the workers could well lead to improvements of ongoing production and to taking up manufacture of known types of products, but in order to generate new knowledge, the "common person" would need training in ways essentially similar to that of present-day scientists. If the purpose of the Cultural Revolution had been to make everyone a scientist, it would have been a truly significant step in reconciling science and society, and perhaps pointing in the direction we all should be heading (assuming that people could include in their make-up all the other things important for a good life, besides being scientists). However, all the Chinese did in that period was to abandon science and give its name over to technology. The current Chinese view is that the Cultural Revolution set science back by an entire generation, because that is what it takes to recreate the scientific environments, and in addition it set Chinese technology back by almost as much. I use this example, because it does say something about the role of physics in society and as a basis for technology. Even if the exact usefulness of a given scientific enterprise may be difficult to see, the existence of a healthy scientific community would seem to be a direct prerequisite for technological advance in general.

But is it a one-way relationship, from science to technology? Weisskopf thinks not. In an article about technology (Weisskopf, 1980), he gives a number of examples of the opposite kind of transfer: That technology may give rise to new physical insight, for instance when the construction of steam engines lead to the formulation of thermodynamlcal theory. In recent times at least, physics has become so intermingled with technology, that Weisskopf talks about a symbiotic relationship. One thrives from the other. The nature of this relationship will be further looked at in Chapter 2.

Not only are physics and technology interconnected. It is a characteristic feature of many current issues in science, that they embrace several of the traditional disciplines (examples are energy and environmental sciences). However, the present scientific institutions are not necessarily suited for a fruitful interdisciplinary approach. This is one reason for raising interest in teaching physics to non-physics students, and in teaching non-physical subjects to physics students.

Back to the article by Weisskopf. Weisskopf is inclined to accept the view of science as being culture, but he is unhappy about the notion of acquiring knowledge with the purpose of controlling nature. The statement that "knowledge is power" is, according to Weisskopf, not always in agreement with historical facts. We have gained knowledge, which would allow famine and slavery to become eradicated. But then why is it, that many people are still hungry and do nonsense work. We have the knowledge to end all evil and yet there is war all over.

Of course, Weisskopf realises that having the power to do something also implies having the power not to do it. Some would certainly argue that precisely those possessing the power to do good will want to prevent this knowledge from being used in a way that increases equity, because that would deprive them of their privileges. However, Weisskopf seeks a cultural explanation for the failure to use scientific knowledge to solve urgent social problems: Young people in Western societies are becoming anti-science oriented! They question scientific objectivity and indulge in all sorts of Eastern religions. This bothers Weisskopf, because he sees the Eastern religions as mixing the working spaces of science and religion, which according to him ought to be kept strictly apart from each other (this is entering into a philosophy of science question, where Weisskopf takes one particular position. Such questions will be pursued further in Part III). The failure to create a liveable world is blamed on the anti-science attitudes of young people, rather than being addressed to those directly responsible for the misery we are in, because Weisskopf has an implicit belief in the rationality of political leadership. But the responsibility for the misery is, at least in democratic countries, resting with a much larger group of people than those in governments. The political leaders in democracies could conceivably be under influence of an anti-science mood prevailing in society at large, but the real responsibility for this situation lies with those who, by misusing science and technology, have given rise to the mistrust regarding the capability of science and technology to help reaching the good ends, and not the bad ones.

Is there a way that science in general and physics in particular can become a positive contribution to creating a humane human society? I believe that this was always a possibility, but that until now it has never really been used. I further think that one fundamental reason for this has always been the lack of broad participation by all groups in society in determining how science and technology is to be used, and under which kinds of social control they are to be used. To allow such a broad participation in assessing the use made of or contemplated for certain scientific results and derived technology, everybody must have a notion of the nature of the science involved. This does not necessarily mean a physicist's training in physics, but simply a knowledge of what physics is about, and which methods are being used. at such a level that participation in a social debate involving physical Issues is not precluded because of insufficient knowledge of physics.

PROBLEMS AND DISCUSSION ISSUES

PROBLEM 1.1

Will a person standing in a bus and facing the driving direction fall backwards or forwards when the bus starts?

DISCUSSION ISSUE 1.2.

What do you think the goals of physical science should be, and how should these goals be approached?

DISCUSSION ISSUE 1.3.

Should man use physics as a means of ruling nature?

DISCUSSION ISSUE 1.4.

Who should science and technology be serving? Are they doing that today?

PROBLEM 1.5

A soldier drops a bomb through a hole in the bottom of an air-plane. Can he watch the bomb descending by just standing at the hole inside the flying air-plane, or does he have to bend down and put his head through the opening? Disregard air resistance. Explain the reasoning behind your answer, and probe into the significance of the request to "disregard air resistance". Such commands are common in physics textbook problems. How do they affect your possibility for using everyday experiences to check your results?

CHAPTER 2

PHYSICS AND TECHNOLOGY

After World War II, a boom in spending for research and development has taken place in the United States and many other countries (see Fig. 2.1). It is not surprising that this high level of R&D spending has led to a similar boom in new technology. Some areas, in which new technologies have been rapidly added, are electronic component design and miniaturisation, nuclear techniques, space technology, microprocessor control systems and genetic engineering. Several of the technologies involved derive from basic physics research.

During this same period, a widespread wave of mistrust in technology has risen in many parts of the world. This is hardly surprising, and a straightforward explanation for this mistrust would be that the influx of new technological gadgets has been too fast for people to absorb. This is an easy explanation, which does not lead you to suspect, that there could be something wrong with some of the new technology itself. However, this is precisely the accusation made by many of those opposing specific types of new technology:

It is unacceptable because it cannot be controlled, or because we know too little about its sideeffects to be able to decide, if we really want it. This sort of critique has been raised against technologies such as super-bombs, new types of missiles, nuclear power and gene-manipulating biotechnologies.

A more general view is taken by by social critics such as Mishan (1969), Illich (1971) and Schumacher (1973), who think that we are getting both too much technology and technology of the wrong kind. Mishan started the debate by asking if indiscriminate worship of growth in economic activity was the right path to follow. He found that some of the expansion in the 1960ies was clearly counterproductive, and that it involved more negative than positive impacts. Around 1970, the focus was on environmental effects and the possible depletion of the Earth's finite resources. Negative impacts, of which the environmental ones were very demonstrably present, were in many cases judged to be lacking in any compensating beneficial effects. For example, several mass produced consumer products did not serve any discernable human need, and in fact the products could not be sold unless they were marketed with a psychologically suggestive kind of advertising, aimed at deceiving the customers.

Schumacher was influenced by the doomsday prophecies of Forrester and Meadows (1971), intensively discussed in the early 1970ies. According to these prophecies, the world would collapse due to resource depletion or ecological disaster, unless the ways of producing goods were immediately changed. Schumacher noted that technology was in the centre of this issue, because «rather than lightening the burden of man, it eliminated only the enjoyable, skilful and productive types of human work». By breaking the production process into small pieces, the machines leave only boring, monotonous operations to the worker. The overview of the production process is lost for the working person, and with it goes creativity and work satisfaction. The solution, according to Schumacher or to Illich, is less productivity in the economic sense of that word, and a halt to the present kinds of technology. Instead, a different kind of technology should be developed, a «technology with a human face». It should suit man, and because man is small of size, his technology should be so too: «small is beautiful». This technology of the people, or "intermediate technology" as Schumacher calls it, must necessarily be decentralised, if it is to restore the joy of creative productivity to every member of society. Schumacher finds it more important that everybody is engaged in creative work with his or her hands, than to manufacture a large number of (even useful) products (this is a bit like the philosophy behind the Cultural Revolution in China). To this end, he quotes Karl Marx for saying: «They want production to be limited to useful things, but they forget that the production of too many useful things results in too many useless people.»

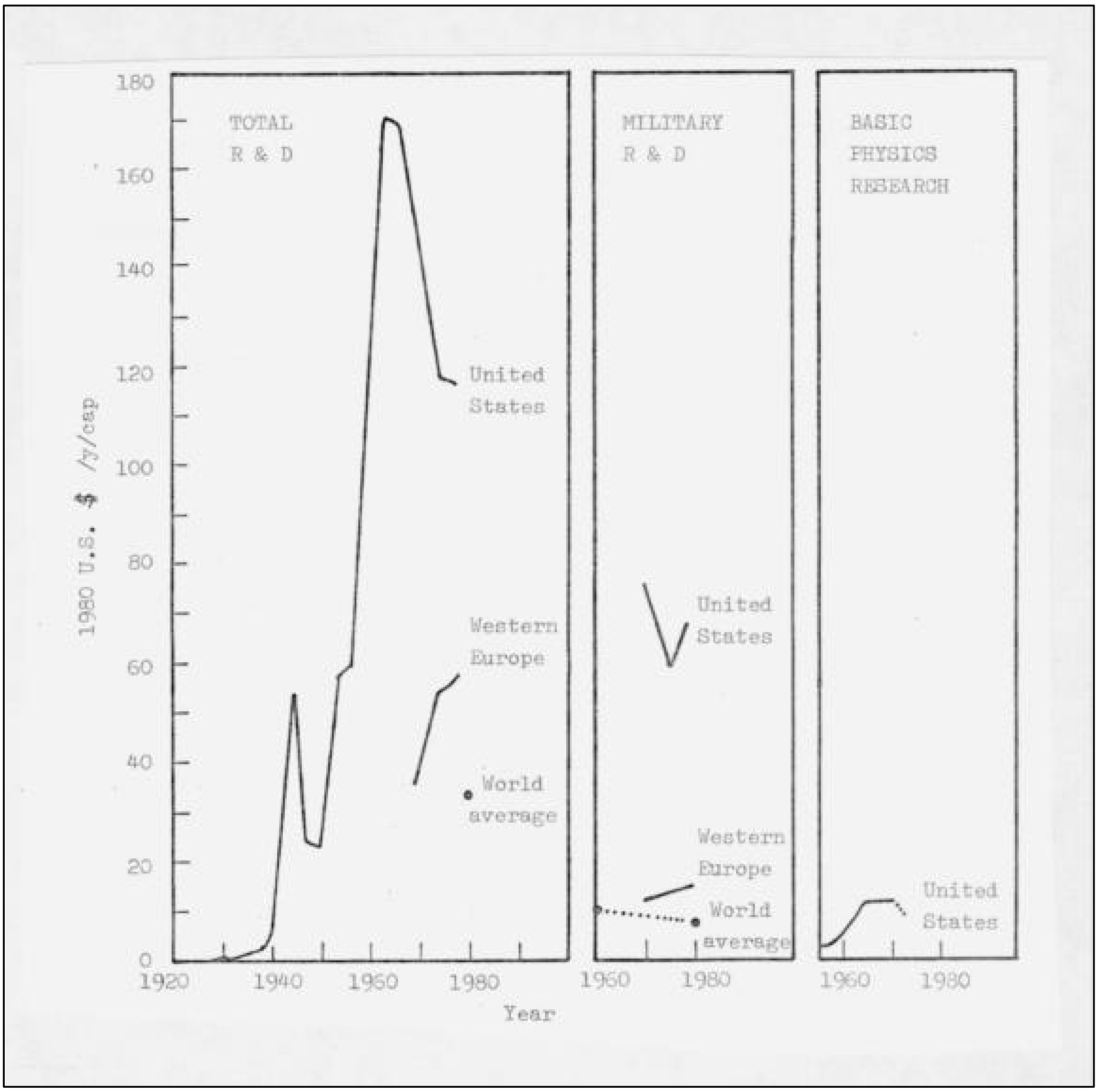

Fig. 2.1. Governmental spending on research and development (excluding capital investments), .expressed per capita per year in fixed prices. Environmental science is included in physics figures. (Based on United Nations General Assembly, 1981; R. Sivard, 1980; U.S. National Academy of Sciences, 1972, with price deflators from U.S. Department of Commerce, 1975 and 1981)

While Schumacher approaches the problems of technology from a moral standpoint, Dickson (1974) uses a political angle. He does acknowledge that a host of new technologies have had benefits associated with them. However, these benefits are increasingly being overshadowed by negative consequences which, to Dickson, include environmental and resource-related impacts, but are as much suppression and manipulation of individual human beings. We have become dependent on machines in practically all our activities, and technology is increasingly playing a political role. Technology is related to the distribution of power in society, and to exerting control. Technology and social organisation are mutually reinforcing each other, on the material as well as on the ideological plane. The choice of technology is made to support the ruling class in the material sense, and it also serves as a symbol of the ideology of the society in question - for example the ideology of hierarchical leadership structure (which is equally prominent in the traditional capitalistic countries in the West and in the formerly centrally planned, said socialistic countries in the East).

Dickson defines «alternative technology» as technology which, in its choice of tools, machines and techniques, reflects methods of production that do not suppress or manipulate people and do not exploit the natural environment. The alternative technology is a necessary, but in no way sufficient, condition for creating a non-exploitative society based on full participation of its members. On the other hand it is a political struggle to create an alternative social framework within which it is possible to develop the alternative technological solutions. To claim that the choice of technology by itself could produce a more desirable society would be technological determinism, for which Dickson sees no justification.

The view of technology as a political tool is shared by commentators of quite different inclinations. Ullrich (1979) states that capitalism and big-scale industry (the technology of which supports capitalism) must be defeated at the same time. He points to the construction of concrete Utopias, imaginative scenarios of social structures with alternative technology and alternative ways of production, as a very important step towards the realisation of a humane society in ecological balance. Weisskopf (1980) finds the present industrial organisation anti-democratic in many respects, because it favours specialisation and is based on centrally controlled authoritarian leadership. We need at more popularly controlled technology, which probably can be achieved only by smaller units of production, he says.

Let me now try to look at the structure of a given society, with special attention to the way in which production takes place, and to the dynamics of social structure - that is its change with time. Fig. 2.2 gives the distribution of people employed in the U.S., divided into broad categories of work, as it has developed between 1860 and 1980. The job categories are agriculture, industry, services, and information. The service sector comprises: private services, commerce, liberal professions and all public services except those with an information transfer involved. The information sector includes in part manufacture of information-related hardware and software (which is thus taken out of the industry-sector), and in part any job involving as a main component the transfer of information (teaching, telecommunication services, and so on). The reason for singling out information-related work is to demonstrate that it is in this area, that nearly all the growth has taken place since 1950. One component of this growth is related to new microprocessor technology, a technology specifically aimed at increasing the amounts of information that can be transmitted within society, by decreasing the cost and increasing the speed of information flow.

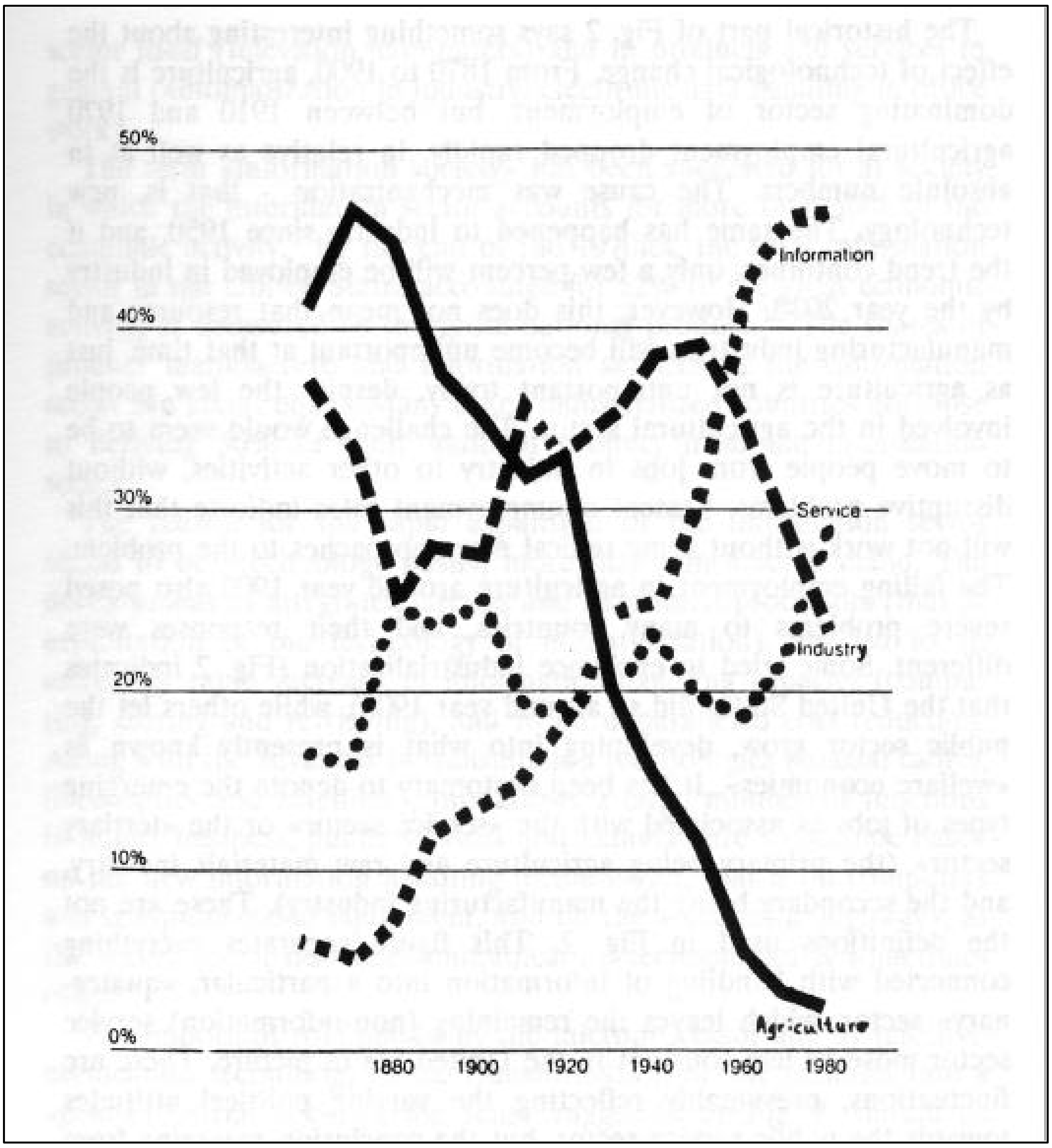

Fig. 2.2. Distribution of all employed people in the United States, as function of time. (Based on M. Porat, 1985; cf. also Strassmann, 1979)

The historical part of Fig. 2.2 says something interesting about the effect of technological change. From 1870 to 1900, agriculture is the dominating sector of employment, but between 1910 and 1970 agricultural employment dropped rapidly, in relative as well as in absolute numbers. The cause was mechanisation - that is, new technology. The same has happened to industry since 1950, and if the trend continues, only a few percent will be employed in industry by the year 2030. However, this does not mean that resource and manufacturing industries will become unimportant at that time, just as agriculture is not unimportant today, despite the few people involved in the agricultural sector. The challenge would seem to be to move people from jobs in industry to other activities, without disruptive problems. Present unemployment rates indicate that this will not work without some radical new approaches to the problem. The falling employment in agriculture around year 1900 also posed severe problems to many countries, and their responses were different. Some tried to enhance industrialisation (Fig. 2.2 indicates that the United States did so around year 1900), while others let the public sector grow, developing into what is presently known as «welfare economies». It has been customary to denote the emerging types of jobs as associated with the «service sector» or the «tertiary sector» (the primary being agriculture and raw materials industry, and the secondary being the manufacturing industry). These are not the definitions used in Fig. 2.2. This figure separates everything connected with handling of information into a particular, «quaternary» sector, which leaves the remaining (non-information) service sector more or less constant in the United States picture. There are fluctuations, presumably reflecting the varying political attitudes towards the public service sector, but the conclusion emerging from Fig. 2.2 is that the only real strong growth sector in the last one hundred years of U.S. history is the information sector.

The rise of the U.S. information sector between 1880 and 1940 may be attributed to an indirect effect of the large increase in industrial mass manufacture capability: To be able to sell the rapidly increasing volume of goods, advertisement had to be refined, and the customers had to be educated, in order to be able to use and appreciate the new products. Both advertising and customer education is clearly to be dealt with by an «information sector». The second rise of the information sector, during the period 1945-1980, is more directly related to new technology, both in the information sector itself (television, computers) and in products and services in general (automatisation in industry, electronic data handling in office work).

The term "information society" has been suggested for at society in which the information sector accounts for more than 50% of the economic activity (Valaskakis and Fitzpatrich-Martin, 1980). By the end of the 1970ies, the total information sector in the United States accounted for 52% of the gross economic activity, as measured by the gross national product. The shares of product manufacture and information services in the information sector are about equal. Many other industrialised countries are close to deriving 50% of their national product from the information sector.

The reason for the rapid expansion of the information sector seems to be «technology push», more than consumer demand. The development of integrated circuits and later microprocessors (that is, exploitation of the technology of miniaturisation), has led to an extremely rapid increase in information-handling capacity (computing, storing and retrieving), and to an unparalleled cost reduction. Along with the advances in transmission technologies (coaxial cables, fibre optics and satellites), this allows a large number of functions in home, business, public services and manufacture to become based on the new information handling technologies, that is on computers and computer-aided equipment, and on the «electronic highway», as the whole set of new telecommunication technologies is sometimes called.

The important role played by the microprocessor and by telecommunication technology in the transformation of our societies into a «post-industrial age», in the sense suggested by Fig. 2.2, should be sufficient reason for choosing these technologies as examples of technology in needs of social assessment. But the invasion of such technology in everyday life takes place so rapidly, that we will have to act fast, if we are to reach any conclusions based on assessment, before the pattern by which these technologies are incorporated into our social systems have become to rigid. The steam engine and the automobile are examples of technologies introduced without preceding assessment, and the problems of for example road safety and access to private cars did not receive qualified attention until a stage, where the fundamental patterns of automobile use were practically impossible to change. As a more recent example, the nuclear power industry has received some qualified assessment while the penetration of the technology was still modest enough to allow for reorientation or cancellation of the program (more on this in Chapter 3).

A major concern related to the emergence of an information society is the future of work. Will it be possible within the human labour marketplace, as it exists in capitalistic countries, to create alternative jobs in a situation, where the manpower requirements of both agriculture and industry have been virtually eliminated, and where microprocessor use is eliminating most office and other administrative work, and possibly also jobs in the education and leisure sectors? The new jobs created in system design and programming will be far fewer than the number of jobs eliminated, and computer operator and system maintenance jobs will also decrease in numbers, because reliable, low-maintenance systems are penetrating the market.

Should we not be happy with the prospects of a future with hardly any work left? It seems to be the most boring and repetitious work that is disappearing, so we should all be able to enjoy short working hours and to indulge in creative activities! Alas, this is not the trend of the actual development at present. Instead, we see increasing unemployment and an associated pressure to decrease wages (or at least their purchasing power). It is true that a scarcity of qualified people in some areas, including specialists in the computer hardware and software fields, does lead to a few well-paid job opportunities. But this will, if the trend continues, create a society where a relatively small elite possesses good jobs, while a large part of the potential working force is unemployed. The unemployed group may increase from the present 10% to perhaps 50%, constituting a massive proletariat, which among other things will be unable to share many of the benefits of an «information society».

There are several visions of such a society. In one version, the unemployed proletariat is kept pacified by precisely the kind of technology that made them jobless: trivial television entertainment, computer games, and so on. Another version sees society divided into two completely separate sub-societies: one comprising, the employed people with a rich possession of material goods - including all the varieties of computer and telecommunication gadgets - the other sub-society is formed by the unemployed people, who live in an informal economy, provide services to each other on an exchange basis, and have very little access to material consumer goods produced by the first sub-society.

An alternative scenario (A «scenario» is a snapshot picture of some future situation) would assume, that the negative sides of the divided society (which could easily spur friction and violent conflict) would be recognised at an early stage, and that a more equal distribution of salaried job opportunities would be assured.

One way this might come about, is if industry would feel limited, as regards marketing of its products, by the lack of purchasing power in the unemployed group. If this group gets to be 50% of the population or more, the marketplace considerations will begin to tempt industrial leaders to rethink the case for an economic redistribution policy, and they may influence political leaders to help in recreating the widest possible consumption potential.

The democratic process of selecting political leadership in principle makes it possible for an unemployed majority to force a redistribution policy through. Previous experience indicates that this is unlikely to happen, because the privileged group plus the fraction of the unemployed people believing that they may soon «make it» to the privileged group, will vote together to preserve the existing system (just as many workers today vote together with the upper middle class, for similar reasons).

The obstacles to the development sketched above should, however, be recognised. It is contrary to the basic power structure of a capitalistic society, not just because it would limit the free enterprise system, but perhaps more seriously because it would offend a very fundamental ideology of capitalism - that of work as a virtue. From early childhood, the members of present capitalistic societies have been taught that "idleness is bad", and that "work is a healthy occupation for human beings". So high is the ethical value attached to work, that it would be very difficult to adapt existing people to a future with practically no work to do, no matter how the economic distribution is arranged. New generations may get an altered attitude towards work (this may already be the case at present for some young people, who have never had a job), but no attempts have yet been made to give this attitude change a positive direction, neither in school education nor in parents' upbringing of their children. This is hardly surprising, considering the deep rooting of the present work-ethic in the parent generation.

A Canadian group called "GAMMA 8" has tried to classify the types of Society that might emerge as a result of the microprocessor and telecommunication «revolution». Table 2.1 summarises some of their main scenarios in schematic form. There are scenarios with acceptance both of the «central electronic highway» and the microprocessor technologies, other scenarios with rejection of the central electronic highway but acceptance of a decentralised use of computers, and furthermore scenarios in which both the new technologies are rejected.

The «centralised» information societies may be of three different kinds:

1) The first scenario, which is the one most in line with the current reality, is one that uses the telecommunication system to transmit more or less trivial information. The content consists of entertainment, such as television series with standardised plots, and similarly superficial encyclopedic information. The use of a central electronic highway to multiply the channels of such material will reinforce the trivialisation of life-styles already associated with most of the present use of television technology for one-way

communication.

2) The second scenario envisages the use of the system to collect and store information regarding individual citizens, with the purpose of using it in the interest of a totalitarian, ruling group. This could be a dictator or a fascist government, or it could be any institution or power, such as the banks or police intelligence offices presently gathering information of unknown quality on citizens. The control that such a system could exert over people, if expanded to a two-way (that is transmitting information in both directions), penetrating coverage, is enormous. Psychological conditioning of people to accept violence, to purchase certain consumer products, to vote for particular political leaders, etc. (e.g. by monitoring the response to certain pictures shown on the television screen and using the information to plan further transmissions), could lead to levels of mind control unknown to classical totalitarian rulers.

3) The third of the «central highway plus microprocessor» scenarios is an utopian one, with an ideal content. It would be guided by public interest and it would offer lifelong education, active participation of individuals, as well as of community or interest groups, in debating issues of social importance, including those involving technology choices. I call this scenario utopian, because it requires a major reorganisation of present societies, in order to become a realistic proposition.

The two «decentralisation» scenarios (Bl and B2 in Table 2.1.) assume the use of microcomputers, either on an individual basis or centred around territorial (community) or subject-oriented (interest) groups. The rejection of the central electronic highway will introduce a lot of redundancy, but it will reduce the possibility of outside control. One reason for the latter claim is that the hardware (microprocessor) producers can place little restrictions on how the computers are to be used. Another reason is that the effort of learning to program is not so hard that a user cannot avoid any restrictions imposed by the software producers. This makes computer technology much less prone to ideological control than many other technologies. However, the basic structure of digital information handling techniques does of course imply a certain narrowing of the «thought space» (by excluding considerations which are difficult to put in digital form). The redundancy associated with parallel efforts made in the decentralised scenario may not be seen as a deficiency in a society, where work has been nearly eliminated and the large masses of population must find their values in life through human relations and mind activities.

The scenarios rejecting both the central electronic highway and the computer (but not necessarily an information society) may either lead to an impoverishment of large groups in society, or to the creation of a society consisting of more or less attractive, organised subcultures. Both scenarios envisage a development during which the people out of jobs actively resist the introduction of additional high technology, in a vain effort to avoid further reduction of employment. In one version, the job-less sink down to become an apathetic proletariat, characterised by trivial activities (such as drinking). In the other version, the job-less may become organised into informal groups, living in «communes» with agricultural and/or craft production based on low or intermediate technology, plus service-oriented activities such as music performances. Alternatively, the job-less may become organised into formal groups, or «cults», based on religious or ideological dogmas, often with a fundamentalist-style reinforcement of the particular rules of the cult.

Table 2.1. Types of «Information Societies»

A1: Central electronic highway used to transmit trivial information

A2: Central electronic highway used to support a totalitarian system

A3: Central electronic highway and microprocessors used to further public interests

B1: No central electronic highway. Computers used by individuals

B2: No central electronic highway. Computers used by small common interest groups

C1: All high technology rejected. Trivialisation of life-styles

C2: All high technology rejected, small groups or cults are created on the basis of cultural activities or common religious beliefs.

Most of the discussion above has been confined to domestic use of microprocessors and telecommunication techniques. However, the potential severity of the impacts, which these technologies may have in society, is as much connected to their use in business, administration and industry. Office work is being replaced by a direct communication between the customer or client and a computer with its database. Executive managerial functions are also becoming conducted by everywhere-present microcomputers linked to large ones by the telecommunication network. Not only may business and office work be performed from home terminals, but the terminals (including some computing capacity) are already becoming portable. In industry, design is more and more becoming based on computers, and so is manufacture and distribution to and from warehouses, through the use of robots of increasing sophistication. Distribution to consumers could in the future become more computerised - today only the planning part of the distribution job is usually made with computers.

The use of satellites for telecommunication makes information an international commodity. Threats to national sovereignty and national identity are clearly involved here. The Canadian study (Valaskakis and Fitzpatrick-Martin, 1980) lists a number of questions related to the industrial use of microelectronics: To which extent will the use of microelectronics replace dull, repetitious or dangerous work? Will quality improve? What are the resource implications? Will depletion of non-renewable energy and mineral resources decline or accelerate? How would unemployment, underemployment, working hours and retirement plans become affected? What advance plans have been made for dealing with these problems? How should school education be adjusted in order to cope with the implied changes in job and non-job activities? What are the psychological effects of a large number of people having to work very closely with microelectronic devices? Does the development of the information society influence people's sense of dignity and purpose? Would there be scope for alternative ways of self actualisation?

If the microelectronics revolution continues to lead to increasing unemployment, it is likely that the self-help economy, that is exchange of services for reduced pay or reciprocity (but avoiding tax and social security payments), will become more widespread. In countries such as the United States or the Scandinavian countries, the informal economy presently amounts to 5-10% of the gross national product (Bonke, 1983). However, the value of, say, repair work per-formed outside working hours for one self or friends (without pay), household work and voluntary work for community or interest organisations is not included in these estimates. Weekday household work of Danish people in jobs declined from an average of 2 hours 38 minutes in 1964 to 1 hour 52 minutes in 1975 (for male workers, the average increased from 25 to 36 minutes - sic!). In the United States, women not employed outside the home spent 7-8 hours a day on housework, throughout the period 1926-66 (Scott, 1982). While the amount of household work thus seems to have been constant or declining, the other types of non-employed work are likely to have increased, along with the reduction in regular working hours during this century.

Non-household activities not involving any employment relation-ship are precisely the ones predicted to increase in most of the future scenarios of Table 2.1. Such activities would give possibilities for establishing the personal relationships, which are presently coming naturally through everyday encounters at common work places. Seen from the capitalist employer's point of view, the dispersion of employees to individual home computer terminals would seem to offer ways of preventing labour organisation and of reducing union power. Opposing strategies must be found by the workers' side, if the new information technologies are not to create uncontrollable shifts in the power distribution, to their disadvantage. The question of power is a very important one in connection with the introduction of new technology. Who is going to own and operate the centralised communication systems? Who will decide what information should be sent along the network lines? Who will be producing the data bases and software associated with the systems? Is there any way this area can come under the control of social interests?

Another concern is the commercialisation of information. Many kinds of information have in the past been exchanged freely in society. Will they now have to be paid for? Will a change in attitudes evolve, by which information from computerised databases is valued higher than information from individual people? Could I some day be asked to pay 50 cents for the information, if I ask somebody at a street corner for the way to the nearest bookstore? The «obvious» conclusion, that increased labour-saving technology will increase our total leisure time (no matter how good we are at distributing it among us), is no longer so obvious. Already Linder (1970) pointed out that the advent of the service economy has led to a decline of service rather than the opposite. The reason for this must be sought in the economic scheme for allocating resources in most present societies. Thus we are about to identify problems with new technology, which could not have been anticipated by pure technology assessment, but only by an assessment of both the technology itself *and* the ways in which it may become embedded in society. For technologies, which are supposed to have a marginal impact, it may suffice to consider the current structure of the surrounding society, but if the technology may lead to both physical and ideological changes in the social environment, then the dynamical development of the entire society must be part of a proper technology assessment» (one reason for perhaps avoiding this term altogether!).

PROBLEMS AND DISCUSSION ISSUES

DISCUSSION ISSUE 2.1

Is it true that microprocessors do not carry such a solid ideological message as for example nuclear reactors or sports cars? One may argue, that everybody can find out what some of the microprocessor issues are, from a small computer kit bought for under $ 100. This is certainly not the case for nuclear reactors.

PROBLEM 2.2

This and the next problem are meant to illustrate advantages and disadvantages of scale. Consider a town distributing heat through district heating lines. If the heat is produced by co-generation (combined heat and power generation) or solar collectors, it is practical to add heat storage facilities to the system, in order to be able to deal with any mismatch between production and demand (this could be on a short term, hourly or daily basis, or it could be on a longer term, seasonal or even annual basis).

Assume that heat is to be stored as hot water below the boiling point, in insulated containers of a given (say cylindrical) shape. The question is whether it is best to Install one storage unit in every household, or to have a common store for the whole town.

You may proceed on the basis of cost, or - if the cost differences between the central and decentralized solutions are assumed negligible - you may simply compare heat losses through the surface of the containers.

PROBLEM 2.3

Consider a community covering its heat needs either by district heating or by individual boilers/furnaces. Let L be the total length of district heating lines needed to serve the community by transmitting heat from a central plant. L will increase, the more dispersed the settlement pattern is.

One would guess that the central heat production with a district heat transmission system would be more appropriate for dense settlements, while individual heating without any district heating lines would be the best solution for a very dispersed kind of settlement.

Try to calculate the average distance L, for which the two systems break even (cost the same). To do this you will need to distribute the cost of the district heating lines over the number of years they will function. Here you may simply use an effective depreciation time (try 10 or 20 years), by which you divide the total investment cost in order to get the annual cost. You may assume that it costs 2 cents per kWh of heat to produce the heat centrally (say by co-generation), but 6 c/kWh to produce it decentrally (say using one furnace per building). The cost of a well-insulated district heating pipeline may be taken as $50 per meter, installed. Assume some average annual heat consumption, such as 400 million kWh (corresponding to about 20 000 dwellings in a temperate climate).

How would it affect the calculation, if houses were better insulated, so that the annual heat requirement were two or four times lower?

DISCUSSION ISSUE 2.4
Do you think that it is OK to introduce new technology, if it has certain problems to be solved "along the road"? Would it affect your answer, if the problems were known or unknown, when the decision to introduce the technology was taken?

DISCUSSION ISSUE 2.5
Do you agree, that large-scale technology and mass production have had a destructive influence on our societies? One intermediate technology development group tried for years to build an intermediate-technology tractor for use in developing countries. However, they never got below the price of commercially available, mass produced tractors, despite lower performance aspirations. Does this prove that Schumacher was wrong?

DISCUSSION ISSUE 2.6
What is your personal opinion of the information society? Will it help to oppress ordinary people, or will it make them (us) more free? What is needed to ensure the latter outcome?

PROBLEM 2.7
Consider a business firm, which on average meets with business partners 3 times a day. The business partners are located at an average traveling distance of 30 kilometers from our firm. Discuss the following alternatives:

A: One person travels to each meeting and back in a company car.

B: A TV conference facility is used to conduct all meetings (each participant has one TV monitor and one TV camera with microphone, and transmission is over the telephone network or perhaps a microwave sender and receiver). Estimate the daily energy use associated with the two alternatives. Estimate the cost to the company in the two cases.

You may either ask around to obtain the necessary data, or use estimates (guesses!) of your own.

DISCUSSION ISSUE 2.8
Does one have to understand technology to take part in discussing and assessing it? (Look at examples, such as mobile phones, GPS devices, laptops, television, automobiles and nuclear reactors).

CHAPTER 3.
PHYSICS AND SOCIETY

Physics can be viewed in ways other than as an approach to understanding relations in nature, or as a basis for technological development. In this chapter, I shall look at the physicist as a servant to public interest. The physicist shall be viewed as a member of an independent, critical institution in society. This institution would ideally be charged with taking the side of the public at large, and any underprivileged group in particular, against attempts of exploitation and misinformation - whether by industry, by governments, or by other actors on the political scene.

Such «critical science» is not constituting any large fraction of the total science effort today. Indeed, only a handful of «professional» scientists are involved in critical science, and many of those doing critical studies are «self-made» scientists and science students, often involved in voluntary work for some public interest group. Some-times, these «activists» succeed in interesting professional scientists in their issues, and thereby obtain access to more of the accumulated scientific knowledge, than they could themselves acquire easily. It is evident, that there are societies, in which outspoken groups with a critical attitude towards the use of science and technology have not emerged, perhaps due to constraints imposed by the prevailing political system. But I believe that all societies know of examples of critical voices raised within the professional science establishment, either from individual scientists or from professional societies, with names such as «scientists for social responsibility» or «concerned scientists».

In order to understand the weak position of critical science, one may start by asking why research is undertaken, who pays for it, and who uses science. Furthermore, one may ask questions such as: how are scientists recruited and taught, and who are in the best position to make use of openly published, scientific results.

Research in industry is naturally aimed at improving products and production, or at developing new products. Sectorial research, such as in government laboratories or laboratories owned by organisations, is project-oriented and often required to support an official (political) view or a position held by the organisation in question, and to suppress divergent views. Research at universities and at national laboratories beyond the imposed work is as free as the scientists want and the funding process allows. This means that it will not be really free when it is financed on the individual project basis, with allocations decided upon by peers in research councils or similar institutions. The remaining «free» research is that based on block allotments to research institutes. The use of such funds is «free» in the sense that salaries are secured independently of the individual research topics being taken up. There may still be pressures from within the scientific environment, or from the science community in general. Ingredients in this socialising pressure include peer review, editorial refereeing procedures used by scientific journals, subject divisions defining what are the acceptable research disciplines (institution headlines), and psychological mechanisms favouring the acceptance of boundaries implied by the interest areas of colleagues. The training of physics and other science students is a long process, during which the value system of the scientific community is often very effectively imprinted on the student. This may be through textbooks, through the kind of problems given for the student to solve, or through the examples set by the teachers. As a result, the student's imagination is conditioned to operate within set constraints as to what is possible and proper for a scientist (Martin, 1979).

I now take a look at the situation for working physicists. The constraints mentioned above are very obvious to those who are employed in temporary jobs. But also researchers in more secure positions have to consider their reputation within the physics community, if they want to be invited to speak at conferences, to have their results published in reputable journals or to obtain research funds for particular studies. The virtues expected from a physicist include specialisation and hard work. Both tend to reduce the applicability of research for critical and socially oriented purposes. Specialisation, because it makes it harder to put the results of one scientist into a wider context, and hard work, because it leaves the physicist little time to catch upon social issues in debates on science and technology. There is no time to read cross-disciplinary literature, or to contact social groups other than the narrow circle of colleagues with the same specialisation.

When this breed of physicists serves as advisors (say to governments) in matters involving the social impacts and implications of new technology, their outlook is likely to be very conventional and generally positive regarding applications of research, especially if it originates within their domain. The only reservation they express is usually, that some additional research would probably be needed.

A thorough discussion of the role of scientific advisors is contained in Primack and von Hippel's book *Advice and Dissent* (1974). It basically argues that an advisory tradition such as the one found in the United States can be made to function in the public interest, provided that it is made very open, so that scientists who are not members of an advisory committee can get full access to the assumptions made, the material used by the committee, and to any calculations made by the advisory body, or by its sources of information. Also non-scientists must have access to such data, and often it is the coalition between critical scientists and community interest groups, that have led to recognition of major flaws in policies based on the advice of expert committees.

This raises the question of the role of experts, and the question of how members of advisory bodies are selected.

Experts are usually specialists, which implies that the criticism stated above applies to them: Experts are often less qualified than the average person, in matters concerning social impacts. Furthermore, not all those playing the expert role are really qualified: Very often, technical experts in a narrow field are commenting on broad social issues, as if these were within the field of their expertise.

The participation in debates involving technology assessment should rather be broadened to comprise all members of society. The role of the «professionals» should therefore be to help stimulate such a debate rather than to try to internalise it. Advisory bodies are often heavily biased in favour of the new technologies being assessed. It is sometimes the case that members of an advisory board have a direct economic interest in the introduction of the technology in question. This is not surprising, as noted by Diesendorf[19], because the experts who are most qualified and knowledgeable with respect to a given technology or a given product, are normally those employed by institutions promoting that technology or product. However, this does not make them particularly suited for addressing questions judgement about that technology or product (rather the contrary), and often they cannot speak freely of shortcomings and flaws in the technology or product, because of pressures from their organisation.

Primack and von Hippel discuss a number of case studies, including the debates over supersonic passenger jet planes, pesticides (DDT) and herbicides (2, 4, 5-T), antiballistic missiles, food additives (cyclamate), plutonium fabrication hazards and nuclear reactor safety. They draw the general conclusion, that although it is rare that critical scientists and public interest groups attain their primary objective (such as preventing the introduction of a given technology), they often succeed in reforming the thinking of public servants in official regulatory bodies, so that these start to take environmental and social issues into account when setting standards. The acceptance by Primack and von Hippel of this outcome of scientific criticism implies a confidence in the civil servant class as being open to enlightening, even if it contradicts the narrow interests usually built into the training and socialisation of government employees. In many European countries, the experience is that only an alliance between critical scientists and popular movements can create the massive pressure needed to make room for environmental and social concerns in the technological decisions of big industry, large concessioned public institutions, and of governments themselves. If a dialogue between concerned scientists and official assessment experts is not accomplished by public pressure, the critical concerns will become quenched in the end.

This is quite in line with the lesson from the environmental debate: The significant date in this case is the publication in 1962 of Rachel Carson's *Silent Spring.* Concern over persistent pesticides in the environment became spread from the lunch-tables of a few dissident scientists to the entire reading public. So convincing was Rachel Carson's warning of the possibility of losing our natural environment, that the U.S. Presidential Science Advisory Committee (one year later) recommended the reduction and eventual abolishment of the use of persistent pesticides. This was in contrast to the U.S. Department of Agriculture stand at the time, and it took ten years, before the Federal government finally conceded to ban DDT. The initial reaction of the established scientific world to Rachel Carson's book was negative. A review in *Chemical and Engineering News* asked for Miss Carson to be silenced, while the reviewer in the journal *Science* suggested that she lacked perspective, as «most scientists who are familiar with the field, including government workers charged with the responsibility of safeguarding the public health, feel that the danger of damage is slight»[22]. At that time, there were no hard data to support such «feelings», and it was precisely the procurement of such data, which was urged by Rachel Carson. The quotation from *Science* contains some of the most common attacks on critical scientists: The scientists who are really familiar with the subject, that is the experts, all agree that there is no problem. Only this single outsider has a diverging view, probably due to lack of knowledge of the field, and due to erroneous calculations of the risks. The quotation also makes reference to those «charged with responsibility» towards public health. They are seen as impartial judges of pros and cons, and as experts in making such evaluations, at the service of the entire population. No one should expect experts carrying such responsibilities to suggest measures that might curtail the productive sector on which we all thrive, as long as the danger of damage is only hypothetical! In other words, «responsibility» is viewed as implying that health and environment should pay for any uncertainty in assessing risks. The debate over the supersonic passenger aircrafts started in 1965, notably as a result of the criticism launched by the Swedish aeronautical engineer Bo Lundberg (1965). In the United States, the debate was kept alive from 1967 to 1971 by the «Citizens' League Against the Sonic Boom», with physicist William Shurcliff (1970) as the dedicated driving force. This citizen's group finally did reach its objective: a ban on supersonic flights over the U.S. The debate started with the health implications of the sonic booms, but went on to the very complex matter of ozone depletion in the stratosphere. A wealth of scientific studies were initiated and used in the debate, with over-interpretation and mis-interpretation in both directions (Martin, 1979; Primack and von Hippel, 1974). The interesting part of this story is how the critique from a few scientists, in opposition to the majority of «experts», later developed into a broadly accepted scientific point of view.

Nuclear reactor safety gives another unique example of the role a critical scientist can play even when opposed by the entire scientific and bureaucratic establishment. In early 1971, a notice from the U.S. Atomic Energy Commission regarding a 30-day public hearing period before licensing the Pilgrim reactor in Massachusetts caught the eye of economy student Dan Ford. He contacted the physicists Jim MacKenzie, Henry Kendall and Ian Forbes of the M.I.T.-based «Union of Concerned Scientists». They had already spent a year trying to understand the emergency core cooling system **of** reactors. None of them had previous knowledge of nuclear engineering, but the news of failures in the Atomic Energy Commission's testing of emergency core cooling systems had made them wonder what was going on. Together with Dan Ford they published their doubts about reactor safety (Norman, 1982), which subsequently spurred a world-wide reassessment of the whole problem. Kendall pointed to design flaws in the emergency cooling system, and successfully defended his points of view during a set of national rulemaking hearings in 1972 (Primack and von Hippel, 1974). His opponents were the nuclear reactor industry and the Atomic Energy Commission (AEC) spokesmen. Kendall had earlier (November 1971) had a chance to speak informally with scientists within the AEC, and to his surprise found that they shared many of his concerns. However, they were not allowed to speak freely on safety issues by the AEC administration, which feared that changing the licensing rules (the rules for permitting new nuclear power plants to start operation) would have legal repercussions for reactors licensed earlier, and the reactor industry might become hurt.

As a consequence of the critique from the «Union of Concerned Scientists» and numerous public interest groups across the nation, the AEC commissioned a comprehensive reactor safety study, to be directed by the M.I.T. nuclear engineer Norman Rasmussen. Rasmussen seemed a safe choice, as he had already publicised his opinions, that reactors caused no significant risk to society (Rasmussen, 1972). However, in the end, Rasmussen and his helpers were unable to bring the calculated risk down to acceptable levels, so the AEC decided to take the work out of Rasmussen's hands and to rewrite it in a more palatable form (U.S. Nuclear Regulatory Commission, 1975). The 3000 page report fails to give key information on how the calculations were carried out, information that would allow others to check and discuss details of the estimates. Still, basic flaws in the methodology of the calculations were detected (Lewis *et al.*, 1978), and after the Three Mile Island reactor accident, the incompetence of the Atomic Energy Commission and its successors (changing names seems to have been a favoured step in dealing with criticism) has been clear to everybody, and the reactor industry has been facing a vanishing market.

The experience in some other countries has been similar to that in the United States, as regards repeated downwards revisions of nuclear safety claims. In Denmark, this has led to a de facto abolishment of nuclear power. In other countries, the authorities have responded differently, either by virtually announcing it a criminal offence to oppose nuclear power (France, the Soviet Union), or by openly admitting that it is a risky enterprise, but that it is manly to face up to risk! (England). A detailed account of the course of the debate in different countries may be found in a book by Jim Falk (1982).

A grotesque notion penetrating much pro-technology risk assessment is that risks associated with new technology can be accepted if they are no higher than risks already accepted. This statement is made by Rasmussen (1972) and also by those claiming that there is no risk associated with extended exposure to low-level radiation (discussed e.g. by Diesendorf (1982). What it boils down to is that these «experts» would accept any new technology leading to numbers of deaths and injuries no higher than those associated with traffic accidents. This position is brought forward very openly in an ironic attempt to rebut Ford and Kendall's concern over reactor safety, by using identical phrases to discuss automobile safety (Saxe and Murray, 1972). The conclusion is that in order to avoid the risk, automobiles should not be licensed to drive at more than ten kilometres per hour. A very sensible statement, which leaves the critical reader in doubt of the direction of the irony.

Whether scientists are critical or not is often a question of whether their eyes are open for «externalities». The expert may overlook problems, which an «inexperienced» person sees at once. For example, nuclear reactor experts maintained until 1981, that radiation levels in worn-out reactors would be insignificant after a few decades. In 1976 Marvin Resnikoff, working for «New York Public Interest Research Group», identified nickel-59 as an isotope formed in nuclear reactors by neutron impact on materials. This isotope has a half-life of 80 000 years, so it will not decay in a few decades. In 1979, an undergraduate student at Cornell University, John Stephens, found another isotope - niobium-94 - formed in significant quantities within reactors, which the nuclear industry had similarly overlooked. Not until 1981 did the U.S. Nuclear Regulatory Commission admit, that these two isotopes would give rise to dose levels substantially above what was considered acceptable.

Until now, I have almost exclusively looked at the positive sides of critical scientist intervention. There are of course negative examples as well, where provocative statements have been made in an effort to seek fame. In a way, this is in line with the norms imposed by the scientific community: to find something surprising, novel, something that can revolutionise thinking. Sensationalism is frequently seen in all areas of science, but it is often accepted by the scientists, if it is believed to help attract more funding (for example medical research in a speculative stage is often publicised in news media for this purpose). Yet, critical science of the kind that offends industry or public institutions is nearly always accused of sensationalism by colleagues in the scientific community. I suspect that the truth is, that honest concern is a bit more frequent and sensationalism correspondingly less frequent among the critical scientists as compared with the uncritical ones. Still, it must be discouraged, and the best way to do this is by public exposure. Other critical scientists could play a role in revealing any unfounded statements being made. In contrast, some conventional research institutions have been forbidding «their» scientists to speak publicly without clearance from institute directors! The purpose of such control should be obvious.

How could we reinforce the position of critical science through science education and the education of scientists? I believe that general science education is important in creating a social under-standing and support of critical science. However, the specific training of researchers also needs modification. A degree of specialisation should be seen as one necessary dimension, but one that has to be accompanied by broadness and interdisciplinarity as another compulsory dimension.

Students should learn about the biases likely to occur in science, and particularly in areas where science touches the real world. Students should be made aware of the power structure in scientific enterprises. They should ask where the money comes from and to whom the results will be communicated, they should know the limitations of working for part interests, such as unions or employer's organisations, or even public interest groups gathered around specific issues. A critical scientist must be free to criticise all sides.

PROBLEMS AND DISCUSSION ISSUES

DISCUSSION ISSUE 3.1

Can you see any ways of making scientists more "available" to the common citizen? Would it be any good. if all groups in society could freely hire university scientists to look into issues of their concern? Could the critical scientist retain her or his independence under such a scheme? Aren't the successful critical science stories we know all depending on dedicated work by unpaid or underpaid scientists, who finally wins over the highly paid but less dedicated experts of the other side?

PROBLEM 3.2.

In reactor safety evaluations, a central problem is to calculate the probability of accidents that have never happened before. One approach is to break the accident events up into sequences of part events (valves failing to open, electrical switches failing to operate, human operators pushing wrong buttons etc.), which have occurred so often, that statistical data on their frequency are available - and then to combine all the part events that could lead to a given accident and combine their probabilities by standard logical rules.

Another approach would be to wait until the actual frequency of accidents is large enough to allow a statistical treatment. This has effectively been used in air-plane safety analysis but cannot be used in reactor safety assessment (why?)

What are the merits of these approaches regarding completeness (that all possible accidents have been included), built-in accident rate (accident types known to occur but considered of such low frequency that it is not worth the trouble to try to avoid them), ratio of unexpected to built-in accident probabilities, and finally the use of the accident analyses to improve designs in the direction of higher safety?

DISCUSSION ISSUE 3.3.

Discuss the risk concept in connection with accidents of very low probability but very devastating consequences. Is it like multiplying zero with infinity: one can get any result? Are there accidents of so grave consequences, that they are unacceptable no matter how small their probability?

CHAPTER 4.
PHYSICS AND WAR

Science in general, and physics in particular, has always made contributions to warfare, as far back in history as we are able to identify scientists as a separate group of people. One may recall the story of Archimedes using burning mirrors to set fire to the Roman fleet coming to conquer Syracuse (although there is no evidence to verify the story, the writings of e.g. Euclid shows that the use of burning mirrors was well known in Greece at that time). Physical principles were used in early throwing devices, in tools for entering fortified structures, and later in the construction and use of firearms. In the nineteenth century, the «natural scientists» - that is a person combining scientific knowledge with philosophy and an eye for practical applications - became replaced by professionals with a greater degree of specialisation. Along with this change, the technological development accelerated. A division of labour was introduced between scientists and engineers, and the engineers were at first employed by the military. Only later did the non-military needs for science application become so intense that special civil engineers were called for. The notion of «pure science» (or «basic science», in contemporary terminology) emerged in order to be able to distinguish between scholarly science and engineering, or applied science. In Europe, this separation became especially effective, because universities did not accept engineering as a science, and special polytechnical schools or technical highschools had to be established. In the United States, engineering science became more readily accepted within the university structure.

The nuclear bomb project in the United States during World War II (the «Manhattan project») led to a new reorientation of science, and it lead to very special attention being given to physics. The wartime effort had involved the creation of large weapon's laboratories, employing teams of scientists, engineers and specialist workers. After the war, these became the core of National Laboratories. They employed physicists in hitherto unprecedented numbers, and an organisation into laboratories of more manageable sizes became natural. This also lead to the creation of sharper dividing lines between sub-disciplines of physics, such as atomic physics, nuclear physics and solid state physics, and in particular the development involved a more rigorous distinction between theoretical and experimental physics.

The weapon labs became the scientific basis for a rapid progression of arms sophistication. Many industrial manufacturers found it necessary to establish their own research laboratories, in order to cope with the advanced production requirements for either arms or new consumer products, the latter often being the spin-off from the arms development. In some cases, the industrial research laboratories included basic science departments, for example for solid state physics or aerodynamics. The space exploration race during the 1960ies further enhanced this development and added a number of new research institutions involving physics and related sciences.

How shall we look at this development? Were the scientists only called in to engage in military work in cases of national emergency? Did they engage in military work on their own initiative and because they wanted to contribute their knowledge to justifiable wars against evil opponents? Or was military work an expected part of the return on taxpayers' money spent in support of science? In earlier centuries, there may not have been any clear position on this issue. It was assumed that every citizen would do anything demanded of her or him when national sovereignty was threatened. A scientist might be asked to join the armed forces, and it was probably an exception if specific scientific skills were made useful. But as the more specialised uses of science became part of war efforts, particularly from World War I and onwards, it also became more natural to involve scientists in military use of, say, radio communication, deciphering of foreign codes or finding the best aerodynamic shape of air-plane wings for high speed conditions. British scientists, and German as well, found it their moral duty to contribute their brain work to such ends.

Later, the stocks of nationalism fall somewhat in value, and it has become more acceptable to express divergent views on national security and related issues. It is quite understandable, that many German scientists could not wholeheartedly join the war efforts of Hitler. On the contrary, the scientists on the allied side found it their duty to join the fight against Nazism, by contributing their particular skills. They even spurred the nuclear bomb development by bringing to the attention of political and military leaders the vague possibility of building such a bomb during World War II. This unique action by such scientists as Szilard and Einstein, both peace-loving and later to become involved in disarmament campaigns, came out of fear that Hitler's scientists might be working on nuclear bombs (a fear enhanced by hearing of Niels Bohr's conversation with an ambivalent Werner Heisenberg in Europe (Jungk, 1963). The result was that a group of the most talented scientists in history flung themselves into a military weapons program of unprecedented difficulty. Without moral hick-ups they finished that job incredibly fast, feeling that what they did had to be done. Only after the job was finished, and the military took hand of their invention (and used it under circumstances very different from those prompting the physicists and other scientists to lend themselves to the bomb project), did some of the scientists question the wisdom of what they had done.

After World War II, the relationship between scientists and the military has assumed a new pattern. It has become a much closer and permanent association, no longer restricted to periods of war or conflicts. Beneficial to both, would some say it was. The physics research in particular benefited from generous funding during the post-war period (to about 1970), and the military of course benefited from the flow of sophisticated weaponry-ideas generated by the physicists (even though some of the top names withdrew from the military work as soon as the war was over).

Frank Barnaby has put forward the theory, that the «military-scientists» are chiefly responsible for the uncontrolled escalation of the arms race after 1945 (Barnaby, 1981). He sees, in accordance with other recent technology control studies (Elliott and Elliott, 1976), the main actors as: the military, the industry, the bureaucrats and the academic people. They have taken the power out of the hands of political leaders (at least in democratically organised countries), as far as military technology is concerned. However, among these actors, Barnaby sees the military-scientists as being most responsible for the arms race between the United States and the Soviet Union. For example, they are destroying the nuclear deterrence policy by work on anti-submarine warfare. If strategic nuclear submarines were to become vulnerable, deterrence would probably be dead. Why, then, is such research pursued by scientists in the East and the West, when the political leaders seem to genuinely want deterrence maintained? Obviously, the political leaders are not in control. And take a look at the other weapon systems being developed in the weapon labs of the U.S., the former U.S.S.R. and France: precision missiles for the intermediate to long range, space launched weapons and neutron bombs. All such current developments favour those groups in both camps that believe, that a nuclear war can be fought and won. Every time the people and their leadership think they have created a liveable balance, the military-scientists come up with a dozen new ideas which will upset the balance.

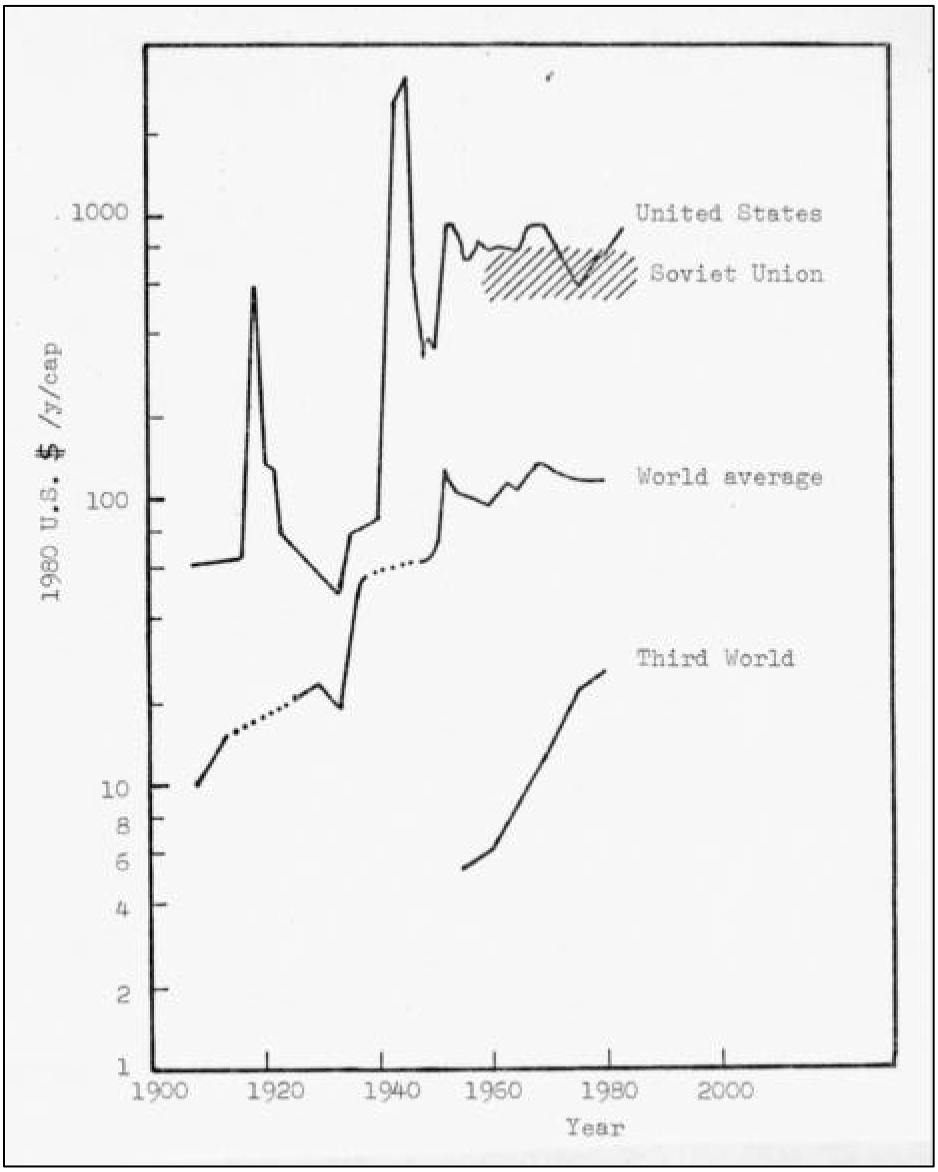

Fig. 4.1. Military spending per citizen per year, expressed in fixed prices (1980 US $, 1978 exchange rates). (Based on United Nations General Assembly 1981; Thee, 1976; U.S. Department of Commerce, 1975; The Boston Study Group, 1979; SIPRI, 1981; Sivard, 1980; Magraw and Isaacs, 1983).

Some undoubtedly, find the arguments of Frank Barnaby too simplistic, arguing that the development just sketched is indeed what the political leaders have consciously chosen, because they may believe that their side has an edge in technological advance. However, I shall pursue the subject a little further, by drawing from the United Nations report commonly known as the *Inga Thorsen Report* (United Nations General Assembly, 1981). In contrast to Barnaby's head-on approach, the Thorsen group builds its arguments up slowly and carefully, drawing on a wealth of evidence before drawing any conclusion. Yet the conclusions drawn are no less sharp. The unique intensity of the post-war arms race is caused by the extraordinarily rapid rate of change in weapons technology. For 30 years, new and improved weapons have emerged at an unmanageably fast rate. Military technology has raced ahead of the process of political assessment and control.

Scientific research is the reason for this misery. The average military product is twenty times more research-intensive than the average consumer product. During the 1970ies some 2.3 million scientists and engineers, 20% of the total number of such qualified persons, were engaged in military research and development work. During the 1950ies and 60ies the percentage was even higher. These numbers do not include people employed within the space programs, although some of their work is certainly defence oriented.

Fig. 4.1 gives an idea of the total military spending in different parts of the world, and Fig. 2.1 in the previous chapter specifically looks at the research and development (R&D) expenditures - in total, for the military and for some basic physics research.

In 1970,some 50% of the U.S. budget for basic physics research was covered by the space program, and some 30% by military or nuclear energy programs. Overall, the United States military R&D accounts for about 50% of all R&D spending by the government. R&D spending by industry is roughly 75% of those of the federal government (U.S. National Academy of Sciences, 1972). That figure is much lower in most other countries. The military part of government R&D spending is near 25% in Western Europe, while in the Soviet Union it is probably higher than in the United States.

It is sometimes argued, that the spin-off from military development has given rise to a number of innovative consumer products and other advances in civil technology, that might not have come about otherwise. This may be true as judged from the much lower R&D intensity of typical non-military products. Those that do require much above average R&D might not have been developed at all, without the «free» technology transfer from military application. On the other hand, this does not give any hint of what might have resulted from spending the military budgets in other ways. The certain thing is that the productivity of investments, as well as their job creation potential, is higher in the civil than in the military sector. One may also point out, as the Thorsen report forcefully does, how much the money spent on the military could have achieved, had it been invested in the social instead of in the military sector. It is worth pointing out, that this would not have implied higher tax burdens, because the money would be spent through the government in both cases. As far as research is concerned, the Thorsen report suggests that the stock of useful knowledge that might have come out of not pursuing the arms race, could have been very large. In other words, the intensity of the military R&D effort does not mean that very much knowledge of broad interest has been created. More would have come out of the same R&D investments, had they been dispersed over all areas of science and not just those interesting from the military point of view. This also means that a shift from military to civil research spending may not just be a question of transferring the scientists presently working for the military. Their attitudes towards scientific and technical problems would in many ways have to be changed in order to become suited for work in the civilian sphere.

Looking at the role played by fundamental physics research, Fig. 4.1 shows that even the total spending in this area, military and non-military, is a small fraction of the total United States military R&D spending. This is of course due to the large component of engineer-ing development contained in weapon's development. Still, the basic ideas underlying new weapon systems are very often provided by the military physicists.

The share contributed to funding a given research field and the influence gained over the field are not necessarily proportional. For example, NATO may derive substantial advantages from supporting basic physics research in non-military laboratories, by amounts very small compared with the total funding received by these institutions. Furthermore, the projects supported rarely have any discernible military importance, but are closely linked to the existing research program of each lab. In reality, only the military scientists know the true relevance of such NATO-supported research to ongoing weapon research. Without knowing the kind of new military systems under study, a university scientist receiving NATO funds would be very, unlikely to suspect any military use of her or his research. Yet by this arrangement, the military scientists can draw on the entire scientific expertise of the institution supported, in areas not covered by direct military research, and at a cost much lower than what it would take to create this expertise from scratch.

Another example of science being directed by marginal funds may be found in many European countries. Here, in the 1970ies, some 90% of all research money came from annual block allotments of governmental funds, at least as far as universities were concerned. These monetary allotments are thus unconnected to specific projects, and are divided internally within each university, usually in fairly fixed proportions between individual institutes. The last 10% of research money is distributed by Research Councils on the basis of specific research proposals and applications. The Research Councils support research in new areas and interdisciplinary work, because these may not easily find support from the fixed allotments to each discipline. In this way, the entire burden of renewing the scientific spectrum and of establishing new fields is resting with the Research Councils. Only after a new Council-supported area has proven its merits, will it be turned into an institute within the established university structure, and then be allowed to take part in the automatic money supply.

By and large, this system has worked satisfactorily in Europe, enabling new fields to get a fair chance to establish themselves, and also allowing the individual scientist once in a while to follow a crazy idea for some time, even if the chance of any outcome of broad interest is small. Of course the fact that her/his basic salary often comes out of the fixed allotment, so that only the additional cost of a given research project has to be covered by the Research Councils, makes this a lot easier. The point I want to make is that this set-up in Europe effectively means that everything new in science, and hence the direction in which research emphasis is moving, is controlled by only 10% of the total funding (the establishment of large EEC programs for R & D has subsequently drawn money away from "free" research, and into narrowly defined development areas).

In the United States, the traditional set-up has been that a much larger fraction of research money, considerably over 50% in recent years, has been administered as project-related, by the National Science Foundation, Government Departments and private donors. In this way the direction and emphasis of science can be changed from year to year, not in a marginal manner as in Europe, but by closing down entire areas of research and creating new ones. The positive side of this has been the versatility created within each scientist, because most of the educated people have had to follow the flow of money. I have friends who started in nuclear physics around 1960, went into space science a few years later, then in the early 1970ies turned to energy and environmental science, and by 1980 saw no alternative but to work on weapons. The interdisciplinary abilities thus created, and the mobility between fields are positive attributes. Looking at many European scientists who consider it unthinkable to change their field or even subfield, the American system offers clear advantages. However, its drawbacks are also evident: Few American scientists would start a piece of research work with less than a 50% chance of getting a publishable result out of it. Few ever touch fundamental questions that might take many years of thinking, with no guarantees of an outcome. The short time horizon of funding forbids it, and so do career considerations in a fluctuating market for scientists.

Under these circumstances, it is not difficult to find reasons for physicists and other scientists to go into defence work. Interviews of college graduates in the United States (Lempert, 1981) show that some, mainly female students, would not join defence programs under any circumstances. But most graduates are either indifferent or generally positive towards national defence needs, and they would take defence work if nothing more interesting is available. The young physics, chemistry and engineering students interviewed had even less reservation to employment in weapon labs, if they were not directly involved in bomb design. But the chief criterion was whether the work was interesting or not, and many of the fields supporting weapon research indirectly were considered more challenging than the direct design of military components.

However, the focus should perhaps not be on the military scientist alone. Another important connection is between the military and the industry. Once an industry has become involved in defence production and has sensed the lesser concern with cost in this type of work as compared with production for the general market, that industry will become interested in keeping new government contracts coming. This again means that the industry will be thinking in terms of new weapon systems that could interest the military and attract government money. Such an industrial company may itself establish a military research branch, and in any case its fishing for more military orders will help to fuel the arms race. The involvement of the scientists is secured by good salary offers or by the absence of alternative job opportunities.

A prominent feature of military research is secrecy. Making the assumption that fruitful new ideas are the result of cross-fertilisation of insights obtained in different areas, secrecy would alone explain, why military science is contributing less to our total stock of knowledge than open science. The gigantic military nuclear bomb program has hardly provided a single new physical insight. All the important leaps in understanding the nature of matter has been made in open science, that is in the international community of independent but communicating and interacting scientists. Secrecy is another agent in speeding up the arms race. If one side is uncertain about the advances made by the other side, it may accelerate its armament efforts more than it would, had it known the true position of the other part.

It was Niels Bohr, who in his open letter to the United Nations (Bohr, 1950) advocated sharing all scientific knowledge, creating what he termed «an open world». Bohr made it clear that his proposal stemmed from his belief, that science and technology offered the solution to the world's social problems. He did not say that sharing knowledge was the same as sharing power. He probably didn't think it was. But political leaders are sure that sharing knowledge is the same as sharing power, and sharing power is socialism in the very basic sense of that word. For that reason sharing information is unacceptable to political leaders in the United States, concerned as they are with the preservation of the capitalistic system, including its emphasis on the right to maintain inequities (one example of which would be unequal possession of knowledge). However, also the Soviet Union is totally against an open world. Not only would openness jeopardise the power of the oligarchial rulers of that country and would make it more difficult for them to keep the Russian people misinformed, notably concerning the military adventures of the regime, but openness is also contrary to the official international policy of the Soviet Union.

Mamontov (1979) described the Soviet Union as «peace-loving», but then added: Peacefull coexistence does not extend to national liberation struggles or to ideological warfare. As long as there are antagonistic classes, the ideological struggle will go on, and no peaceful coexistence is possible. This is seconded by the Chinese Defence Minister Hsu Hsiang-Chien (1978): A war between the Soviet Union and the United States will come sooner or later, because both have imperialism as part of their ideology. The ideological point of view is also in the foreground, when U.S. political leaders speak of the international policy of the United States: to fight communism and to defend capitalism because it is the best available ideology. If it is true that the entire arms race and the quest for a first-strike capability - that is, to become able to eradicate the proponents of the other ideology before they get a chance to wipe out the proponents of your ideology - is due to the ideological struggle willfully chosen by our political leaders, then there is little more to say as long as we support the way in which our leaders are selected. But if there is a grain of truth in the suggestions made in this chapter, that the arms race is fuelled and enhanced by the doings of military physicists and other military scientists, then there is something to say and do: If you are a physicist, then to think through your role in the war game. If you are not, then to think about the kinds of scientists you think your money should be spent on - how you should influence the direction of research and development in your country, and how that entire area of activities should best be controlled by society.

PROBLEMS AND DISCUSSION ISSUES

DISCUSSION ISSUE 4.2. Who do you think Is responsible for the arms race?

PROBLEM 4.3.
Compare the amount of energy, that would be released if nuclear bombs totaling 10000 megatons were detonated over Europe, with the annual energy use in Europe (which on average over the year was around 7 kW per capita in 1983) (one megaton corresponds to 4.4×10^{15} joule). If the nuclear attack lasts for four hours, what would be the average energy flux? (Assume round figures such as 10^{12} square meters for the area of Europe and 300 millions for its population). Compare this with the energy flux of a violent forest fire (some 1.25×10^{7} joules released per kg of wood burning).

PROBLEM 4.4.
Calculate the time needed for one revolution around the Earth of a missile moving at low height, but neither gaining or losing height (disregard air resistance. There is help below, but try without it first).

DISCUSSION ISSUE 4.5.
One civil technology that has derived directly from a military one is nuclear power. How do you see the connection between the military and civil use of nuclear power? Does expansion of the power reactor program benefit the military nuclear energy program, as well as the other way round? Discuss proliferation and the kind of engineering skills developed in countries using nuclear energy, as compared with countries not using nuclear energy. If an agreement to get rid of all nuclear weapons were ever reached, do you think that nuclear power could still be used?

HELP TO PROBLEM 4.4:
The missile must be moving in a uniform circular orbit. Why? The acceleration in such motion is v^2/R. where v is the speed and R the radius of the circular orbit. The gravitational acceleration is GM/R^2, the constant $G = 6.67 \times 10^{-11}$ $m^3/kg/s^2$. the mass of the Earth $M = 6 \times 10^{24}$ kg and the radius of the Earth $R = 6.4 \times 10^{6}$ m. The orbiting time $T = 2\,\pi\, R/v$ becomes about an hour and a half.

CHAPTER 5.

PHYSICS AND WOMEN

Really a non-issue: men and women perform equally well in science generally and physics in particular, bringing to the field all their individual life experiences. Discrimination is generally lower among university students than in society as a whole, but most societies are arranged socially in such a way, that women feel a career choice between reaching the top as a scientist and functioning as a human being, a choice that men are not feeling as strongly. As a result, there are in most countries few women in top positions in physics, even despite equal numbers studying at universities, and in some countries even at the foot of the ladder, there are clear gender differences.

Where female physicists and physics students are few, that is going to remain so for some time, due to the lack of role models and comrades. Some studies point out that in some societies, a different behaviour with respect to physics starts as soon as choices of subjects are introduced in school. Earlier, when there were few choices to be made by the student, the gender differences were seemingly smaller. For instance, after subject choices were introduced in the Danish school, the 1980 top choices of boys in Danish schools were Electronics and Typing, followed by Photography, Computer Science and Motor Mechanics. The corresponding choices by girls were Typing and Housekeeping, followed by Biology, Photography and Drama. In 1980, there were twenty times as many boys as girls choosing Electronics (Hansen, 1981). In Danish Junior Colleges (age 16-19), only 27% of those reading physics at A-level in 1981 were women (Danmarks Statistik, 19183), and at Danish universities, only 3-6% of physics major's degrees are awarded to women (Beyer *et al.*, 1983). The percentage of all Masters or higher degrees in Natural Science taken by women was 11 in 1975, declining from 19% in 1970 and 22% in 1966. For engineering the numbers were 3,2 and 1% (Danmarks Statistik, 1980). The pattern is similar in most countries, as the statistical compilation of Kelly suggests (Kelly, 1978).

Interview studies have revealed, that it is really physics that is being avoided by women. Chemistry and Mathematics are not particularly avoided, at least they are not quoted as reasons for a choice against the branch in Junior Colleges requiring those subjects and physics at A-level. In looking for reasons for sex-dependent attitudes towards physics, one may focus on the substance of physics, on the process of socialisation in given societies and on sociological aspects of physics education - or of course one may look for biological predispositions against physics in women.

The genetic type of explanation is not supported by-scientific evidence. The often made claims of sex differences in the realms of language skills and 3-dimensional visualisation are quite doubtful (Maccoby and Jacklin, 1982). Yet there are societies where many people still think that women are less intelligent than men. Even among teachers this view was dominant according to a Dutch investigation (Jungbluth, 1982). In a similar Danish study, the teachers characterised girls as "constructive" and "easy to teach", while boys were "demanding" and "undisciplined but more interesting students" (Pedersen and Frimodt-Møller, 1983). With such teacher attitudes, it is not strange, that women seem to get less out of their physics education than men, as evidenced by average physics grades accorded them (Beyer et al., 1983; Kelly, 1978; Jensen and Winter, 1980). The same women got at least as good grades as male students in other subjects than physics.

Our societies generally expect less from women in subjects such as physics. This "cultural background" makes is natural for many women not to go out of their way to excel in physics, while the male students know that they are expected to do well in physics and therefore may be making a particular effort to live up to expectations.

The preconceptions are also different. Women generally have a less positive attitude to physics, and rarely see themselves as ending up in a job involving physics. Men, on the other hand, have detailed plans and ambitions for their future from an early age, and physics and related topics are generally top-rated in their fantasies. All this is clearly the result of cultural factors, that is attitudes which society imposes on its members. Tendencies in recent decades have been in the direction of less favourable thoughts of physics by male students, with little change in the attitudes of women.

It is thus quite possible that these cultural factors influence the way in which we teach physics. In other words, it is possible that our schools and other institutions of education teach physics by pedagogical methods more suited to the temper of male than of female students. Differences in "temper", typically described as boys being more active in the classroom situation, while the girls ask fewer questions and avoid confrontations, are of course also quite probably learned and not of genetic origin. Still, their origin does not have to be known in order to make efforts to avoid the possible distortion of the relative benefits derived by male and female students in co-ed situations. Pedagogical approaches aiming at activating both the quiet and the active students ought to take care of this school-related part of the problem.

It will not be so easy to remedy the negative impacts of attitudes derived from life-long socialisation of boys into "boys" and girls into "girls". When reaching the age of 14 or 15, many boys and girls regard physics as male territory. This is true also for girls who choose to study physics: they know that they by their own will invade male territory, and they psychologically prepare themselves for fighting their way through. Still, the imprint of sexist cultural norms follow them throughout their study periods and quite probably also in their future job situations.

One extremely well documented case of discrimination against a woman scientist is found in the case of Rosalind Franklin. Her field was not physics but bio-chemistry, but many of the patterns are similar: her fine work on the structure of the DNA-molecule would almost certainly have won her a Nobel Prize in front of Watson, Crick or Wilkins, had she only been a man! In his best-selling book "The Double Helix", Watson (1968) mockingly expresses his view of women trying to be scientists. He pity the poor Maurice Wilkins who had to put up with this irritating and difficult assistant. Rosy, who was unfeminine but emotional and unwilling to follow his instructions. Watson explains how Wilkins had to repeat all Rosalind Franklin's work to be sure it was done correctly. It is strange, Wilson says, that she was not the daughter "of an unsatisfied mother who unduly stressed the desirability of professional careers that could save bright girls from marriages to dull men". The truth was that Wilkins and Franklin were two scientists employed in the same laboratory on an equal footing, not her as an assistant to him, as Watson immediately assumed on the basis of the sex difference (Sayre, 1975). As far as DNA-crystallography was concerned, Franklin clearly was the more experienced and imaginative scientist of the two. Watson later in his book openly admits that advance access to her results (some might use the word "theft"), was central in cracking the problem of the DNA structure. It is interesting that Watson in an epilogue gives a revised picture of Rosalind Franklin, probably influenced by her untimely death. Still, it would have been difficult for others to get a true picture of what kind of scientist Rosalind Franklin was, had it not been for the warm biography of Sayre, refuting Watson's image of Franklin point by point (Sayre, 1975). The case of Rosalind Franklin is probably not exceptional for women scientists, only it is so well documented.

It is hardly necessary to provide documentation for differences in socialisation of men and women, of boys and girls. Many societies object to women engaging in a professional career. Some societies offer women a "choice" between career and house servant activities (but not both!), and some societies claim to have no sex discrimination. They allow women to do whatever they like, but leave to the women themselves to get through the barriers set by socialisation and to persuade their male partners to share house chores, to stay home when the children get ill, and so on.

The key factor to touch upon, if one wants to change the existing pattern of socialisation, is probably the early childhood indoctrination. The inertia in this respect is strongest in societies where small children stay at home most of the time with their mothers or their grandparents. However, the child spending some time in nursery school or kindergarten is in no way guaranteed to get a different pattern of socialisation. Children learn from each other, perhaps even more readily than from their parents, and if a few dominating children in a group have learned sex discrimination, this may become spread very efficiently to other children in the Institution. Thus, it is a very major task for the pedagogical personnel of children's institutions, if they are to succeed in breaking the socialisation pattern. One may call it symptomatic, that precisely the work in nursery schools and kindergartens is underpaid and most often taken by women. The teachers working in such institutions may, and in fact often do take up the problem of sex discrimination, but they have limited methodological training, and more specific problems, such as those relating to preconceptions of physics, are unlikely to be dealt with.

Sex-related differences in children's toys and playing habits are still significant. Boys are often given toys of a more technical nature than those given to girls. The moral education of many children also exhibits sex-dependent differences. Girls are being taught to make sacrifices for the benefit of others. The basis for this is the reproductive function, but it may have as a consequence, that women get a different approach to problem solving. They are more likely to include external or global conditions in their search for a solution to a particular problem. In some cases that is a definite advantage, but it may preclude formal, abstract thinking, where this means abstracting from the external or peculiar conditions (Røn *et al.*, 1982). Women's alleged difficulty with abstract thinking would then be a direct consequence of the motherhood-preparing socialisation of women from early childhood.

Assuming that the discrimination against women with respect to physics can be overcome, one may still ask if there are such things as "soft sciences" and "hard sciences", the latter comprising physics and engineering, and to some extent mathematics, computer science and chemistry. Do the "hard sciences" scare away large groups of people (both men and women), so that it will never be possible "to give every citizen such an insight into these areas, that they can meaningfully take part in the debates and the decision-making process in cases depending on "hard science" premises?

The author of this book do not think that such "unpenetrable" barriers exist. The implications of that for physics education will be taken up in Chapter 6. The discussion of gender issues may in some cases have aggravated the situation: In a number of Danish high schools, classes which were exposed to guest lectures on the gender "problem" had fewer women choose physics for their university studies than classes not learning that there was a problem. I mention this as a curiosity, as I am convinced that one can discuss such issues in a school class in ways that do not produce this kind of negative impact.

PROBLEMS AND DISCUSSION ISSUES

DISCUSSION ISSUE 5.1

Are the sex ratios in educational institutions with which you are familiar any different from those quoted in the text above? Have you given it any thought, why the two sexes are represented in the numbers they are?

PROBLEM 5.2

If one male can dig a certain ditch in one hour, how long will it then take 20 women?

DISCUSSION ISSUE 5.3

Try to recall when, as a child, you started to form a picture of physics and an attitude towards the subject. Do you think that picture and your attitudes were influenced by your parents, by other children, by reading or television, or by what?

DISCUSSION ISSUE 5.4

Many societies today see a shortage of qualified physicists. Do you think society should make an effort to use some of the reserve, which must lie in women that could make excellent physicists but will not choose it as things are now? If yes, then how?

CHAPTER 6

PHYSICS AND EDUCATION

Is our physics education in schools suitable for preparing people to a participatory role in society's deliberations on issues such as new technology? Are our school teachers prepared to give their classes this type of education? How do we educate the teachers, and how do we educate those who teach the teachers?

Since understanding the role of science is so important to everyone, we should not stop at asking how scientists are educated. We should also ask, to which extent scientists contribute to public education in areas related to their research fields. Should active scientists perhaps be given more responsibility towards adult education?

In many countries, research and teaching are tied together, so that all researchers must teach, and all teachers at university level must do research. This clearly gives a different science education as compared with systems, where most researchers are working in the somewhat isolated atmosphere of pure research institutions (for example, in the United States, researchers have even been physically separated from the real world, in the special communities for scientists at National Laboratories such as Los Alamos, Livermore, Oak Ridge and Brookhaven).

One thing to discuss at once is whether the early education of physicists should differ from the physics education of non-physicists, or of young people still undecided on what they are going to use their education for.

In countries with one main line of education up to college start (possibly with some choice between subjects), one may say that a common education of potential future physicists and non-physicists has been chosen. However, this may not be the kind of educational system preparing students to social participation in the way I have been advocating. It may instead imply that everyone will be taught "as if" she or he were to become physics majors at university. Such views, leading to an organisation of physics education as a step by step preparation for a university degree, are unfortunately very common, and it is an obvious way of making some students (those not willing to act as if they wanted a physics career) hate physics and block their minds for any input with that label.

The other school system, where students are at several stages divided into branches and levels, e.g. mathematics-natural science branches versus language-social science branches, will inevitably lead to large population groups being unable to i participate in discussions with a physics content. The physics student will similarly lack in familiarity with the subjects of the other branch, but experience shows that these subjects are easier to catch up upon later, than physics and mathematics appear to be to the language or social science student.

A group of junior college students in Denmark (age about 16) were asked why they had chosen this education (Nielsen and Thomsen, 1983). Some 60% answered that it was to prepare themselves for further study, while about 40% wanted to improve their knowledge in general. Thus it is perhaps not surprising that the physics curriculum is organised with future studies in mind: It starts with classical mechanics of point particles, goes on to cover simple laws of heat and electricity, and somewhere at the end mentions atomic physics and - if the teacher has time left - some modern physics and applications of physics in society. The interviewers also asked the students, which physics subjects they themselves would like to hear about. Modern, frontline physics topics came in first, along with applications of modern physics, while classical physics and particularly its applications came last. Even with a positive initial attitude, it is easy to see how students may become discouraged from physics as a subject.

If it were commonly accepted, that the purpose of physics education is to prevent certain groups of people from feeling outside in social discussions involving application of physics, the curriculum would have to be drastically modified. This goes for all levels of physics education, including the training of professional physicists. They should be prepared to become catalysts of public debate, rather than to see themselves as a group of experts. The way to achieve this is to sharpen the critical awareness (indeed to breed critical scientists). I believe this would also benefit research, because the best qualifications for innovative research are also openness to revision of basic ideas and awareness of what goes on in other disciplines of science.

Assuming, that a more ideal physics education would become available, one may still ask if physics is for everyone. Are there people who will never be able to enter the world of physics? Is it fundamentally different from the world of say literature or history studies?

This issue has been discussed in terms of a distinction between "soft" and "hard" sciences, physics being the favoured candidate for a "hard science". Is "hardness" an inherent feature of certain fields? Or is the hardness Introduced along the way, by the kinds of socialisation pressures exerted on children and school students?

If we look at young children, from nursery school age to early primary school years, we see no sign of physics being regarded as a "hard" science. Children eagerly explore the laws of physics, by dropping and pushing objects, tearing materials apart, investigating sound, sight and bite! Already during the first few years of life, the child has established a wealth of empirical laws of physics, and is able to use them in a predictive mode, and to combine them by logical deduction. Only later - often after starting primary school - do an increasing fraction of the children become alienated from physics.

The American-Danish physicist Dick Mattuck saw this as a direct consequence of the absence or near-absence of physics from the curriculum during the first several years of primary school (Mattuck, 1981). When the subject is finally introduced, it is insisted that physics be quantitative (measurement oriented) and based on mathematics, rather than quantitative and Intuitive, that is the way it was experienced by the children at the pre-school level. In school, a fictive world is introduced, where personal experiences are regarded as less important than indirect knowledge (text and numbers found in books or written on the blackboard). This method of teaching will socialise people to think of physics as a hard science, one that is for the few selected ones. The "Mattuck laws" of physics in our society are shown in Table 6.1.

While it is true that people may become alienated from physics through the present pattern of socialisation and the present school system, it is not so certain that the reasons have anything to do with the distinction between qualitative and quantitative methods. If anything, a continued restriction to qualitative treatment of physics, which is common in B-level courses, transforms physics into a kind of story-telling, which in the long run enhances the alienation, because the students cannot answer any physics-related problems (or relate to them if they are met in a social context) by reasoning and numerical calculation based on such teaching. When the connections between phenomena, as they are described by physics, become a set of disjoint postulates to be learned by heart, then the laws of physics get a status similar to that of religious dogmas (in fact they are frequently mistaken for such dogmas), and the students become further alienated from the priesthood formed by those capable of formulating and manipulating the laws of physics.

TABLE 6.1. The laws of physics, according to Mattuck

1. Don't think children can understand physics: Physics is for adults.
2. Don't think ordinary people can understand physics: Physics is for the experts.
3. Don't think women can understand physics: Physics is for men.
4. Don't think physics can be quantitative: Physics is accurate measurements and long equations.
5. Don't think physics has anything to do with imagination, intuition or feelings: Physics is logical.

I would thus maintain that in order to avoid alienation of large groups of people, the physics education must convey to the student a grasp of the way in which physics makes use of quantitative relations and models in its attempt to formulate theories describing relations between and characteristics of the objects studied. The question then becomes, how this is best achieved, without losing part of the audience.

It certainly has a negative effect in this context, that physics - as Mattuck pointed out - is not taught continually during the years of adolescence. A transformation is required, similar to the introduction of "new math" (usually comprising set theory and letter algebra) from the first grade in primary school. Neither mathematics nor physics is harder to understand than reading and writing, once they are seen as related to everyday experiences and needs, just as reading and writing are.

The Danish junior college interview study (Nielsen and Thomsen, 1983) finds, that of the girls in the mathematics-natural science branch, 5% find mathematics the most difficult subject, while 43% finds physics most difficult. Of the boys in the same branch, 7% finds mathematics most difficult and 24% physics. Among students in the language branch (as it existed then, reading mathematics but no physics after age 15). 18% of the girls find mathematics the most difficult subject, 65% physics, while 24% of the boys find mathematics the most difficult, and 46% physics. The language students also dislike these topics, while none of the mathematics or natural science students dislikes mathematics, and only a few dislikes physics, although they find it difficult (mostly girls, cf. Chapter 5). The interviews suggest, that the categorisation of students into those who can handle physics and those who believe that physics is "beyond them" has already been accomplished at this stage.

Thus, in the present situation there do exist such-things as "hard sciences" (primarily physics, but also mathematics and chemistry) and "soft sciences" (biology, geography, and social and humanistic sciences). Engineering and computer science, which are becoming introduced in some junior colleges, go into the hard science category.

One may take the position that the notion of "hard" and "soft" sciences is created by the socialisation starting in early childhood, and that no scientific field, if taken seriously, is inherently any softer (or harder) than any other. Elements of this socialisation process are the different conditioning of boys and girls with respect to physics and technology (Chapter 5), and the absence of primary school topics, which could counteract such differences. These factors would alone seem to be sufficient to explain the "hard/soft" attitudes of the junior college students - without having to invoke any intrinsic peculiarity of subjects such as physics.

As noted above, the child already has acquired a number of preconceptions of physic through experimentation and intuition. Some of these are that a force is needed to keep an object moving (because friction is important In many of the everyday experiences of the child), and that things thrown upwards will come back again (because the child has spent all its time in the gravitational field of the earth). These preconceptions do not go away, just because Newton's laws are introduced in school at some stage. The school physics is considered a different world with different rules, and just because a student shows great skill in solving the school physics problems dealing with point particles and infinitely smooth surfaces, this does not mean, that the same student will not continue to consider the preconceptions of physics as valid outside the school premises. Several tests have revealed, that many school students will use their incorrect preconceptions right through high school and college years, if presented with problems formulated in everyday terms, even if they master the correct physical theory when problems are formulated in textbook style (Nielsen and Thomsen, 1983; Clement, 1982; Lie and Sjoberg, 1981).

Let me give an example of such a problem: A stone is dropped in the middle of a pond and gives rise to circular waves extending all the way to the shore. A bottle cork is sitting on the water surface somewhere between where the stone hit and the shore. How will the cork behave, when the waves reach it -

(A) move towards the centre of the pond.

(B) move up and down at the same location.

(C) move towards the shore, or

(D) move in a circle around the spot where the stone hit?

At age 14, 30-40% of those asked gave the correct answer (Nielsen and Thomsen, 1983), while at age 17, 60-85% (highest for students in the physics branch) gave the correct answer. At age 18, the frequency of correct answers had dropped by 10%, probably due to the fact, that waves had been treated in the physics curriculum at age 17. The most frequent wrong answer was that the cork moved towards the shore, indicating a notion of waves as transporting mass. This is a common preconception of physics, having roots in Greek science, but proven false by Newtonian mechanics. Here, the physics teacher-would have an easy task in demonstrating, that the correct theory is much more powerful than the wrong one. More dubious are problems such as Problem 1.5 at the end of Chapter 1. Here the intuitive feeling that the bomb will lag behind the air-plane is indeed correct, had the assumption of no air resistance not been made. Thus, by clarifying and simplifying the problem, the teacher has rendered the experiences and intuition of the students counterproductive. This may contribute to creating alienation, if not used very carefully, but introduced in the right way it does help to clarify the content of Newton's laws, because it is an example of the methodology of abstract thinking: To disregard certain features of the real world in order to exhibit more clearly the building bricks of fundamental laws. Reality depends of several such basic laws and therefore appears very complex to us. Without the thought-experiments of simplification, we would hardly ever have been able to discover any of the fundamental laws.

Fig. 6.1 gives another typical example of the test problems used to identify preconceptions in physics (McCloskey *et al.*, 1980). The preconception is here, that no force is needed to maintain a rotational motion. In the Danish study, 29% drew a curved path and 47% a straight one at age 14. The rest were uncertain or did not draw anything. There were twice as many correct answers among the boys as among the girls (Nielsen and Thomsen, 1983). Not much change in this pattern was observed during the Junior college years (to age 18), for the students with physics on B-level (including natural science students not in the physics branch). For the physics branch students, the number of correct answers at age 18 was 89% of the total, with no difference between male and female students. Among college students in the United States, as many as 51% drew a curved path (McCloskey *et al.*, 1980).

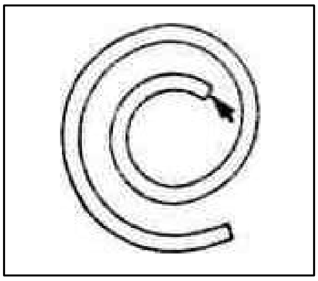

Fig. 6.1. On this figure, a metal tube of spiral shape is shown lying on a table (viewed from above). A metal ball is entered into the tube at the inner end of the spiral (at the arrow). It is made to move through the tube and to exit from the outer end of the spiral with sufficient speed to reach the rim of the table. Draw the path of the ball, from where it comes out of the tube to where it goes over the table side.

In teaching physics to people other than those determined to learn it no matter how it is presented, the teacher must start from the conceptions and expectations of the students. The general interest in modern physics suggests that topics in this domain should be used as a lever for bringing in the social issues and interdisciplinary considerations. A deep understanding of quantum theory is not needed in order to discuss say military applications of nuclear energy, but some insight in quantum phenomena is certainly needed in order to join a meaningful discussion of the health impacts of low-level radiation. As important as the question of how to teach physics is the question of who should be taught. If teaching is only directed at young people, it will take an awfully long time to change the climate for broad participation in social debates with a science and technology component. The answer is adult education. The right to life-long education should be a very fundamental one, particularly in the present industrialised societies, because of the rapid change of their technological structure.

At the university level, the main concern is to educate scientists and science teachers, so that they become capable of inducing the courage into other people - including their students - to fill the roles of social critics with a science foundation. This means that university physics must have two dimensions: depth and breadth.

The depth dimension involves penetrating deeply into a subject, in order to understand its subtleties. All teaching and research institutions acknowledge this and organise their training accordingly.

The dimension of breadth aims at furnishing an overview, an awareness of the main issues in sciences other than one's own, and a willingness to cultivate the border areas between scientific disciplines. To bring this into university teaching can be attempted in different ways. For example, Roskilde University in Denmark uses the following scheme:

Every student has to go through a two-year base education, involving overview courses in all major natural science disciplines, mathematics and computer science, philosophy of science, technology and social structure. However, the main emphasis of the base education is on one-term project studies, where the students (usually in groups) choose a cross-disciplinary subject and formulate a problem with reasonable bounds. They are thrown into this on their first day at university, and have to find literature, talk to teachers in different departments and along the way make use of the coursework, in order to complete a written report to be ready for printing on a specified date. Each report is then presented to and criticised by the other project groups and teachers in a one-day session.

Presently, four such projects take up roughly 50% of the two base years time, with only broad limitations of subjects: resources, scientific theory and experimentation, and science communication. As a result, the students have a broad view of science before they specialise for the master's degree, and they are very good at producing written reports within given deadline requirements (a point where conventionally educated students often fall short).

The main master's program requires the students to take two subjects of equal weight. Any two subjects may be combined, such as physics with history, chemistry with economics, and so on. For each subject, the student must complete three modules (comprising a project with written report plus courses, as in the base years). They are: a depth module, a breadth module (where "depth" and "breadth" are to be understood in the sense described above) and a special module. Work in groups is encouraged, and double-modules combining the two study subjects chosen are considered ideal. The special module project can be an internal scientific one, or a "science as applied in society" topic.

This way of ensuring interdisciplinarity calls for university subdivisions (institutes) with rather conventional subject descriptions. The students must socialise in two environments and they hence form a connection between the disciplines, which the teachers may extend to comprise their research projects. It was hoped that the teachers' research would also be interdisciplinary by this set-up, but this has only succeeded to a small extent.

Other universities have chosen instead to establish interdisciplinary institutes, often formulated around issues important in current social debate. This may have two negative implications, of which one is that basic science knowledge is often weak. This may also be true despite maintaining conventional institutes besides the interdisciplinary ones, because the interdisciplinary institutes have a tendency to feel self sufficient and to avoid co-operation with more established institutes (which on their side may "look down" upon the "impure" newcomers). The other problem is that interdisciplinary institutions formed around current issues often have a short lifetime. This implies a certain waste of resources, because of the time needed to form a scientific environment in a new field, and because of the inertia resisting its being closed down, in case the field is exhausted or no longer of interest. Such problems may be avoided by not defining the domains of interdisciplinary institutes too narrowly.

PROBLEMS AND DISCUSSION ISSUES

DISCUSSION ISSUE 6.1.

Have you experienced your education as being aimed at building up in you a personality with general knowledge in many areas, or did you see each discipline as trying to prepare you for further study and a career In that field?

PROBLEM 6.2.

Look at the trajectory of the ball shown in Fig. 6.2. The motion is supposed to take place in vacuum (in a box without any air). Draw the forces acting on the ball, when it is In the points A, B. C and D (say using arrows indicating the force-direction and if possible reflecting the relative strengths of forces). Give a short explanation of your solution (there are comments to this problem below, for reading after you have had your go at drawing!).

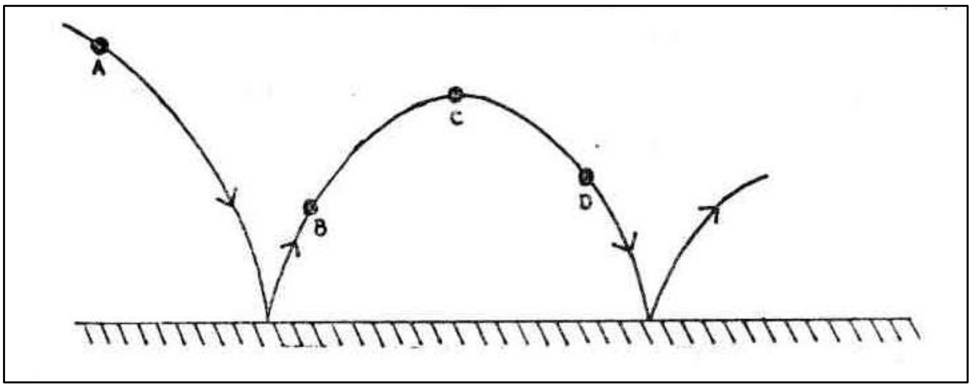

Fig. 6.2. A table tennis ball is made to jump across the table along the trajectory shown here. Discuss the forces acting on the ball in points A,B,C and D, under the assumption that there is no air resistance.

DISCUSSION ISSUE 6.3.

Do you have any suggestions regarding how physics should be taught in school and outside it?

Is it the present physics teaching, that pushes some people away from the subject, or do people have negative attitudes towards physics, which they have acquired elsewhere (that is not through bad physics teaching)?

One suggestion not mentioned in the chapter text, is to somehow make people look up to the physicist as a "hero", who cares little for money but works with high dedication on matters of pure intellectual importance (to the physicist at least). This idea of creating a person cult around the physicist is taken from a little book by the Soviet physicist Kitaigorodsky (1971), aimed at attracting young boys to study physics (yes, indeed - girls are not addressed in the book). If it were a widespread aim to promote such glorification of the scientists in the former Soviet Union, what consequences do you think it had on people's attitudes in questions of science, technology and society interconnections?

DISCUSSION ISSUE 6.4.

Must classical physics be learned before modern physics?

COMMENT TO PROBLEM 6.2.

Only 57% of physics students at a Danish University, which were given this problem, could give the correct answer (Nielsen and Thomsen, 1983). A similar problem given to engineering students at a university in Massachusetts gave rise to only 12% of correct answers (Clement, 1982). Most wrong answers were based on the Aristotlean insistence that there should be a force in the direction of any motion.

Interlude 1: Suppose you are going to work in the knowledge industry.

Exactly, what is it we call knowledge business ?

In 1978, when M. Porat of the U.S. Department of Commerce published a five volume report announcing, that the information sector now employed over 50% of the American work force, a vivid discussion of the new information societies and what they would do to a lot of conventional thinking ensued. The line of arguments went as follows (as expanded from the discussion related to Fig. 2.2):

Before the industrial revolution, everybody worked in the agricultural sector. That is, over 90% of the population were employed on farms and their work effort just sufficed to put food in the mouths of everybody (except for years of poor harvest, which entailed starvation and massive emigration). The remaining 10% were artisans, artists, bureaucrats and non-working aristocracies. This kind of society had endured for centuries.

The industrial revolution changed all that. Now the majority of the population worked in manufacturing industry, and mechanisation made it possible to maintain agricultural production with a much smaller work force. It took quite an effort to accustom people to working in factories. The expensive machinery had to be used efficiently, and this meant that the workers had to work constantly at the machines. This meant a lot of education, because the labour was accustomed to administering their time by themselves and enjoy frequent pauses, when they felt like relaxing. The "work ethics" of the factories had to be imposed on the work force, using e.g. religious indoctrination such as the Christian "idleness is a sin" (cf. Anthony, 1977; the British were very good at this, making England the first industrial nation).

The fraction of industrial workers never got as high as 90%, because of other sectors growing at the same time: a service sector comprising retail outlets and maintenance facilities had to be established, in order to allow the industrial production to grow to its maximum potential, and a certain level of education was needed, partly in order to educate the general population to make use of the industrial products, and partially to provide the engineers and other innovators capable of developing new products for the hungry industry.

The service sector grew and the industry sector became more mature, as the extreme exploitation of workers was gradually reduced as a result of the efforts of unions and governments. The service sector never exceeded 50% of the labour force, as it had to coexist with the industrial sector, on which it thrived. Harry Lindner (1970) complained, that as the service sector grew, the quality of service declined. This could be explained by the salary structure of the people involved: Whereas industrial production benefited from economy of scale, the service sector had no equivalent motor, and whence the cost of service became relatively more and more expensive, relative to the cost of manufactured goods. This in part gave rise to the use-once and throw-away goods, in part led to the establishment of an informal sector, where people would use their spare time to repair industrial goods and to do artisan work, because they could not afford to have it done by professionals. This was of course made possible by the new concept "leisure time".

The agricultural society had no need for a specifically designed time slot for leisure. There was hard work and relaxation mixed into it. The whole day was filled in and no entertainment was available except for possibly playing with the other sex (most novels and short stories at the time dealt with precisely this aspect!). Travelling theatre groups would be so rare, that everybody could be allowed to take the day off, and Sunday's church services were more of an obligation than a spare time activity.

The present situation is characterised by an industrial sector capable of expanding its levels of production (and producing more variety, because the economy of scale has been replaced by intelligent manufacturing, which allows small series to be produced as cheaply as large series), and at the same time use less and less human labour, due to advanced manufacture and control systems, as well as due to a much improved efficiency of the remaining human workers.

This requires continuing education at all levels, and the total education sector (in public and private set-up) is greatly expanding. This is one part of the information sector. Another is the information handling demand rising in both the private and the public sectors of advanced societies. Database information handling, all forms of communications (telephone, facsimile, electronic mail, etc.), news and entertainment systems (newspapers, magazines, radio, television, personal video and audio equipment, etc.) and computer systems for entertainment and productivity - all of these are penetrating society and providing an impressive level of information (but as Harry Lindner would have remarked, not necessarily any increase in the quality of information).

What to include and what to exclude from a formal definition of the information sector is largely a matter of taste. The are border areas and items of different flavour. Porat, for example, includes the computer manufacturing industry and other producers of information equipment. I would prefer to exclude these and keep them in the manufacturing sector. However, these variations are not able to change the overall picture of an information sector becoming of paramount importance (cf. Fig. 2.2). Porat's 50% limit has been passed, not only in U.S.A., but in several countries in Western Europe as well.

The information sector is not a very homogenous one. It includes institutions of learning from kindergarten and primary school to universities and continued education programmes. It includes handlers of knowledge such as post and parcel services, telecommunications and satellite operators (but in my interpretation not the manufacturers of equipment for these services). It includes scientists and everybody doing design for clients or for their own organisation, which may be a government agency or a manufacturing company. In short everybody bridging the gap between basic science and technology, and the actual production. Also belonging to the information sector are the consultants (on projects, management of facilities and people, strategy, etc.), many civil servants, politicians and committee members producing reports about this and that.

There is a wavy line between the information sector and the service sector, because some services basically consist in transmitting knowledge rather than "doing something". However, in practical terms the economic activities of a society can be divided into agriculture, industry, services and information. In a utilitarian context, these are all means to an end, which is to satisfy human needs and improve the quality of life. In between are all the social discussions on what constitutes "quality of life", or I should say that I consider such social debates a vital part of what I see as quality of life.

Then what do knowledge workers do?

A small minority actually create knowledge. By creating knowledge is meant to put knowledge together in a more useful way, such as for instance when a large amount of scattered experience is summarised in a rigorous formula, and that formula turns out to be applicable also in cases not covered by previous experience. By a "formula" is meant a rule expressed in words or in mathematical symbols. It is also creating knowledge, when someone spots that a number of previously proposed rules, which were thought to be unconnected, in fact may be summarised in a single formula. That formula is worth not only the combined value of the old rules, it also gives the relationship between the old rules and thus furnishes new pieces of information.

If the number of knowledge workers creating truly new knowledge is small, then those handling and using knowledge are numerous. Some are transmitting knowledge, some are interpreting it. These are the experts that you may rely on, when you want a specific problem solved. Other experts are popularising knowledge, so that a wider section of the population may take part in debates on say the use of new technology. Some experts are synthesising knowledge, so that it applies to your specific problem. There are knowledge workers performing library functions, ordering knowledge, arranging it in retrieval systems, and updating such database systems, so that they will be able to search for and quickly find the particular information, that clients may ask for.

Designers such as architects and engineers transform knowledge into prescriptions, that can be used in shaping solutions to all kinds of problems occurring in the real world: building roads, houses, air-planes and so on. Others will shape knowledge to suit policy makers, or will prepare forecasts forecasts and scenarios that can assist you in formulating strategies for your company, your government department or whatever business you run. Some knowledge workers form the interface between theory and manufacturing, by designing software, e.g. for computers (where the manufacture of storage media and copying of programs and data to them constitutes the manufacturing process). Knowledge workers also play a role in marketing and sale and service, by studies of market segments, by supplying technical explanations to customers and by keeping track of customer wishes for future improvements of the products.

The use of knowledge may be supervised by knowledge workers, which are thus performing a quality assurance function, comprising not only supervision of standards, but also the constant process of providing motivation for everybody involved in design, manufacture and distribution of a product. Knowledge workers are everywhere, intermingled with the production workers in agriculture, industry and services.

Some examples of knowledge businesses

The company AVION specialises in the design of air-planes. Most of its employees are engineers, and they are paid high salaries. Each design process is called a project, and the project is headed by a project leader. Before the project became a project, it was a proposal, prepared by a task force of five people assigned by one of the company's divisions. The task force was given a budget and a time horizon, which they were obliged to stick to within 20%. Similarly, the project team works on the basis of an activity scheme, that brakes the task up into separate activities supposed to take given number of hours each to complete, and with a staffing specified in terms of skills and experiences required. In addition to assigning total hours though the activity descriptions, the project leader has a fixed expense budget, that may be used for hiring experts, for travel to conferences and visits to facilities using key components of the new air-plane in other contexts.

Sometimes it turned out necessary to revise the activity schemes, and usually in the direction of assigning more hours to a task. If the deadline for the job was firm, this meant requiring overtime work from the project personnel. Overtime was paid at a graduated scale, ranging from 20% above normal hourly wage if there were less than 4 hours of overtime in a given week, to twice the regular salary in case of over 10 weekly hours of overtime, or in case overtime work was required on Sundays or Saturdays after noon.

Statistics has shown that AVION development projects on average have run at 160% of the estimated cost at the initiation of the project, but management believes that this is better than to increase time estimates at the beginning. They fear that there would still be overruns, almost independent of the initial estimates, as long as these are not unrealistically short or long.

BANANA is a young company selling specialised computers for industrial control operations. The company had a visionary boss, who very early came up with a concept for a general purpose computer with a highly sophisticated operating systems and a wonderfully friendly user-interface. The project was started, after a new stock emission approved by the major current stockholders. The project was broken down into a number of well-defined tasks, and each were assigned to a group mainly consisting of free-lance people that had previously assisted BANANA on other projects. BANANA itself had very few employees in its development department. The free-lance people had very different backgrounds: there were mathematicians, engineers, self-educated programmers, even a biologist and a philosopher who loved to work with computers.

Each task is specified in some detail, and specifically the interfaces to other tasks are identified and rigorously defined. Each group works by itself, set its own working hours and group meeting hours. All the groups would meet once a week on the company premises to discuss progress and problems. No fixed time limits are set for each group, but benchmarks have been defined and the groups are required to agree on ultimate deadlines to reach these deadlines, which are important for correlating the work of different groups. A fixed fee for completing each task is negotiated with the group assigned this task, and the group itself is given responsibility for distributing the fee among the group members, according to qualifications and share in the work.

The weekly meetings are usually dense with frustrations and enthusiasm, and the boss is convinced that in the end, he is going to have a superb product and roughly on time. He wonders, though, if this type of work process can be repeated again and again, or if BANANA would have to have a larger permanent development staff for its future products.

Similarities and dissimilarities between the knowledge business and other types of business.

The assets of a knowledge business is mainly in the heads of the people employed. This is in contrast to a conventional manufacturing business, where the chief assets are the products and patents protecting them, and the means of production, such as machines, assembly lines. In both cases, the management skills are important, but the conventional business would seem less dependent on worker's skills than is the knowledge business.

However, there is a development here, in that the blue-collar workers are disappearing or (hopefully) rather being taught a number of specialist skills though continued education programs. The difference between such skills and the skills of the knowledge worker may be, that the production-line worker acquires a series of specialised skills, that may be difficult to transfer to new tasks, whereas the knowledge worker is presumed to possess general skills, allowing her or him to solve new types of problems without other teaching than those inherent in the work itself. Again, the distinction is not sharp, because the knowledge worker also from time to time needs formal continued education, and the industrial worker's skills may be more transferable than they seem at first sight.

Still, if all the workers left an industrial outfit, it is likely (disregarding union issues) that they could be replaced at fairly short notice, whereas for the knowledge-based enterprise, this is usually not so (even if there are similar businesses, from which employees might be attracted, it would probably be at a premium salary because they would have to be motivated to leave their present company).

There are other clear differences caused by the role of creative work in the two types of job. The production-line work has to be carried out at the location of the machinery, and at times co-ordinated with that of others. The example of "distance work" outlined above would only be conceivable in the knowledge business, and there only if the tools required can be accessed in a decentralised way (remote links to computer systems and databases, communication by phone, electronic mail or fax - assuming that the distance workers have the corresponding facilities put at their disposal, or that tools such as phones, computers and fax machines are universally available in the homes of the employees).

The greatest difference probably is in the way knowledge workers have to be managed. Even the word "managed" may seem out of place to many individuals employed in the knowledge business. They are highly independent people, and they usually don't like to be pushed around. Don't tell me what I should do - motivate me! Few of them understand the virtue of placing one person in command. Everyone wants not only to understand, but also to accept any action before embarking upon it. The issue is worth a deeper discussion, but here it suffices to say, that there are advantages and disadvantages in this lack of belief in structured organisations. The fact that other types of workers are easier to "move around" may be only a temporary state of affairs, and one which is equally blessed with advantages and disadvantages. Maybe we move in the direction of a work force where everyone would be characterised as highly educated and skilled, and where the management methods being today specific for the academic workers of information businesses, would tomorrow be the standard everywhere.

How to manage and sell knowledge

My father, who was a consulting engineer, liked to tell the story of how he was called in by an industrial company: Their machinery had come to a halt, and their own engineers were unable to locate the cause. My father then spent two hours going though the production line and making a few measurements. Then he asked to borrow a hammer, and went to a certain place and hit a valve with a single stroke. Now everything worked again, and my father wrote a bill amounting to 5000 €. Gee, that's expensive, said the director of the company, for a single blow with a hammer. Well, said my father, the breakdown of the amount is 1 € for the hammer stroke and 4999 € for the knowledge of where to strike.

This is the knowledge business in a nutshell. Clearly, the value of the service to the industrial company is in tune with the fee demanded. Yet, it is surprising that a number of consulting engineers and other companies in the knowledge business continue to bill their services according to hours spent. They defend this by saying, that at the start of a job, it is hard to tell how hard it is going to be to solve the problem. Therefore, they prefer to be paid by the time spent rather than to quote a fixed price. Most clients are reluctant to accept this concept, because they rightly point out, that there is no incentive to finish the job. They then go for an hourly rate combined with a ceiling on total expense. This is really a silly thing to accept for the consultant. Because first of all, his efforts are to be justified and counted on an hourly base, and secondly, if the job really turns out more difficult than he thought, the ceiling bars him from getting paid for the extra effort.

The only reasonable alternative to time spent contracts is a fixed price agreement, where the client has no business of probing into the actual effort going into solving his problem. If things go well, the consultant can derive a handsome profit, and if the price is right, he will not suffer a loss if the project turns out somewhat more cumbersome than anticipated. Clearly, a consultant who knows what he is doing (i.e. is capable of correctly estimating the effort likely to go into the job), would benefit from fixed price contracts rather than time spent contracts.

However, one must address what happens in a situation of tight competition. In negotiations on a time spent contract, the client will try to decrease the hourly rates. In fixed price contract, the client will try to lower the total price, and would try to provoke a discussion on the actual effort going into solving the problem, that is, he would try to use time spent arguments to find the right fixed price. The point is of course, that if the job is rather trivial and mainly a repetition of things done before, both parties have a pretty good idea of what it takes. If, on the other hand, there are likely to be surprises and problems arising, the nature of which could not have been anticipated with any great accuracy, then a premium for the risk taken would be in place. This again implies, that the consultant (or knowledge worker in general) has to know his or her trade very well, in order to be able to refuse a contract that does not contain a sufficient premium for the risk taken, and still be able to accept a low fee in cases, where the job is really free of surprises, and where the competitive situation warrants such a decision.

Don't let low-level managers decide on contracts. They will look more at employment issues than at profit for the company, and will tend to accept contracts, which should have been refused. Their argument might be, that employees usually cannot be fired at short notice, and thus it is better to take a job at low pay that to have nothing to do. The truth is, that any necessary reductions in staff will be postponed, and that the company will get a blurred profile regarding what it does and at what price.

The other side of the coin is precisely how the employees in the knowledge business are remunerated. Do they work fixed hours and are they paid a monthly salary? Are they paid specifically for overtime, and are there any additional reward structure? Or are they paid according to actual accomplishments, are they sharing some of the risk and profit associated with each job?

The answer must depend on the kind of knowledge business we are talking about. If the company has a volume of business consisting of more mundane tasks, routine jobs without too many intellectual challenges, or repetitive jobs which may originally have involved risk and new thinking, but where a volume of similar projects now makes a "production line" approach appropriate, then that company would employ a suitable number of people that do find secure and repetitive work satisfying, and the company would compete on the basis of knowing how to organise such work in an efficient way.

On the other hand, a company may decide to go only for the innovative stuff, in which case it should carefully select its knowledge workers among those fully competent in doing such work. This means avoiding the "middle way", i.e. people who like routine work but eventually can do innovative work, but who needs to have lots of time allocated to such work, and who frequently make errors and have to redo things. Both characteristics lead to loss of profit for the company. Incidentally, in all types of advanced science, the ability to detect one's own errors at an early stage and correct them is probably the single most valuable skill, given that creativity and ability is present.

Protection of knowledge

There is a lot of creativity and sometimes inventiveness in the knowledge business, and yet it is rare that products of these efforts can be protected by either the laws of intellectual property or patent laws. Intellectual property is largely tied to the form, in which the finding is expressed. If the same content is packaged in a sufficiently different form by somebody else, that somebody else will not be infringing on your intellectual rights.

A concrete invention can of course be patented, and this is important for those sections of the knowledge business that design actual products for mass production. Other types of knowledge business may well create a unique product as a solution to a given problem, but will often not know, if similar problems will or will not reappear in future projects. Therefore, it is difficult to judge, when the effort of going through patent procedures is warranted, and in which regions of the world patent should be applied for. It is a fact that the majority of patents obtained by this type of knowledge businesses are never coming into play.

Many knowledge firms find it more advantageous to publicise their inventions, innovative solutions and other suitable results in technical or scientific journals and present them at conferences. In this way they establish their credibility as problem-solvers, and provide valuable marketing material both for casual readers of the articles, and for potential clients which they can give reprints of the material. Incidentally, this procedure also prevents competitors from patenting whatever is in the article. It has irrevocably been placed in the public domain, but with a clear advantage to the firm from which it originates (and by the way, not all details need to be written down in a technical article!).

Daily management chores

Knowledge workers are acutely aware of the benefits that technology can inject into they work. For example, having the right computer tools available (CAD systems, speech recognition and scientific text recognition software, database, spreadsheets, reusable program chunks and project management programs, to mention a few examples of software in widespread use today), can greatly improve productivity. They are also great to play with, and this has both positive and negative effects on the efficiency of work. Consequently, managers frequently face decisions regarding the level of computing hardware and software to put at their employees disposal.

For several decades, there have been knowledge-based as well as other types of companies, where he management knew less about computers than employees at any other level in the company. The result was (is) often poor decision regarding computing usage and particularly poor decisions regarding computer development projects within the company. Certainly, it is the lot of a manager to make decisions on things he or she does not know sufficient about, and most managers have the ability to grasp the essentials needed for a decision in a very short time. However, there are limits, and decisions involving the intricate cost relationships of computer hardware, software and human resources allocated to software development work are notorious for exposing management incompetence. Of course, the management leans on heads of their computing departments and other experts such as outside consultants, but there is no guarantee, that this leads to a balanced management perspective on the problem.

Management in a knowledge-based enterprise has to deal with two dimensions of problems: those related to the groupings of people and those related to the projects undertaken. The interface between people and projects create special problems, which are often largest for complex, interdisciplinary projects manned with knowledge workers of different disciplines, each characterised by different outlooks, different socialisation and different culture. Different working styles have to be integrated in such a way, that the job gets done efficiently, but at the same time such that respect for the different cultures involved is preserved, even if each of them has to be bent a bit in order to suit the overall purpose.

If the different cultures living inside an enterprise engaged in multidisciplinary work are not managed, they may start to fight each other, and may soon become separate divisions pursuing only selfish goals. Of course, the structure of the organisation may enhance or counteract such tendencies. Thus, organisational problems are often much larger in knowledge-based businesses than in manufacturing businesses, where compartmentalisation is often more natural and at least not destructive.

Management of people in the knowledge business is a separate problem. Management must be able to set realistic time and achievement limits for each project participant, and there are situations, where the manager has to talk sharp to the knowledge worker. Circumstances may call for definite orders to be given, but it is not trivial to determine how to give orders in such a way, that the strange creatures working in a knowledge firm will actually obey them, and not in some way try to circumvent the orders.

Management of information flows within a knowledge business is an important aspect, which - if treated well - can enhance the productivity and contribute to maintaining a good working atmosphere in the company. Knowledge workers are extremely sensitive to lack of information. They are (of course) intelligent and immediately sense, if something important is going on, say in management or board meetings. Delay in conveying infomation will cause them to speculate, that is to make up stories of their own, regarding what may be the trouble. As knowledge workers are imaginative, these stories may soon be much more colourful than the truth, based as they are on hints and interpretations of attitudes read of the management behaviour.

The conclusion is, that precise information must be given promptly. This does not mean that everything should be shared. There may be real business secrets or decisions that have to be kept from the employees. This will be understood, if secrecy is used judiciously and only when really necessary. Sometimes it is possible to give some general information that conveys a spirit of openness without disclosing sensitive information.

The hierarchy of information access seen in many organisations is counterproductive in a knowledge business. Differentiation of information flows on levels of collaborators (based on seniority, rank or whatever) will not work in a knowledge business, because informal lines of communication does not in a group of intellectual people respect barriers of a formal nature. Even the non-academic staff will generally be taken into confidence. They are typically a small fraction of a knowledge business, and often they are the first to know about management decisions, because they take minutes of meetings, etc. They know that they should not disclose what happens at such meetings, but if the academic employees talk openly on an issue at the lunch table, it is hard to expect the secretary not to take part in the conversation.

Nursing and developing knowledge

One very important management task is to nurture and renew the professional culture of the organisation, both in order to keep the knowledge workers performing at their best, and as much in order to make the business ready for new challenges in the marketplace.

The intellectual stimulation of the knowledge worker employed in the business has as a purpose to maintain professional pride in what they are doing. This is not just for the sake of psychology. Professional pride is basic for the approach the knowledge worker takes to her or his work. One of the serious problems in any knowledge business is that the approach taken to solve a problem may be inappropriate. It is very hard to realise that your approach is inappropriate when you are in the middle of a project. Everybody is aware, that the right moment to find out is when the project is still in the planning or explorative stage. But to do this takes a lot of intellectual efforts. If the project team is not "broken in" and accustomed to working together, if management has freed some collaborators only partly from other assignments, then there are good reasons to expect, that the initial stage of the project will not set it on the best course. These remarks apply to all project work.

Among the methods that can be brought into play in order to avoid expensive correction or reworking of a project are the organisational ones pertaining to forming the right balance and collaborative spirit in the project teams, and making sure that each team gets time to do the preliminary phases of the project properly and correctly.

There are a number of specific ways, management can stimulate the professional pride of the company's knowledge workers. It can show that it cares, by organising technical seminars and by making funds available for attending professional conferences, and for preparing papers to be presented at such conferences. It can signal its emphasis on high level professionalism by employing renounced scientists in the fields of its interest, in its research department (if it has one) or as a technical director. The company may combine its quality assurance program with the technical coaching function. This is a very natural thing to do for a knowledge business. Because its ability to derive profit from its projects depends on each project being solved correctly the first time, the attitude moulding necessary for ensuring this should be the basis of quality assurance in a knowledge company.

One way to stimulate professional pride is if the company initiates or takes part in a number of challenging research and development programmes, either internally or in suitable cases with external partners. These serve two purposes: first to development new areas of business expertise, so that the company can adjust to different market needs. Second, to stimulate the employees to be at their best and to enjoy what they are doing. The manager responsible for R&D should keep this two-purpose purpose in mind. There are knowledge businesses, that systematically apply for public funding for R&D work and end up choosing R&D projects according to where is money flows most easily, rather than according to the needs of the company. In order to develop new business areas, the project teams and definitions should of course be optimal for this particular purpose. Regarding the other purpose of involving employees in exciting R&D, it is important that many employees participate, and a reasonable approach will be to launch many short-duration R&D projects in several different fields, so that all departments get a chance to participate over a reasonably short period of time.

Managing knowledge workers: what makes them tick?

Typical backgrounds for knowledge workers comprise masters degrees or Ph.D.'s in science, and engineering degrees from polytechnic institutes or engineering academies. They may be majors of a wide range of subjects, including computer science, mechanical or electrical engineering, chemistry, economy and planning sciences, biology and environmental sciences, to mention only a few. What is termed "untraditional" backgrounds may be in cultural geography, sociology, mathematics, physics, history, political science and so on. The number of people in the knowledge business with untraditional backgrounds is increasing, but they still constitute a minority. In some knowledge businesses, the professional work is assisted by employees with an intermediate-level education, e.g. in programming or CAD drafting. The number of non-professional employees (such as secretaries and service people) is usually small.

In many cases, the knowledge business will employ these people directly from university. In some cases, the candidates would have a previous employment record including public service or teaching and research experience. The implication of this is, that the people entering a commercial knowledge business often have a very limited idea of the business side of the game. It is the task of the company to teach its employees the behaviour pertaining to operating in the private sector.

In doing so, the management should not forget, what made the knowledge workers chose this career: They expect work characterised by a high level of professional challenge, and they expect to develop themselves. If this coincides with the choices made be the company, this side of the problem will be easy, but if the company also takes a body of routine jobs, management should be careful to ensure, that those knowledge workers who expect it and who have the ability gets a fair mix of assignments, with sufficient challenge to keep them going.

As regards the business side of things, management must remember, that the basic attitude of new employees is to do a professionally qualified job, no matter how long it takes. Internal courses should be given, which e.g. through case studies teaches the attitudes that will ensure efficient execution of jobs, and makes every employee sensitive to the balance between the fee associated with a job, and the amount of perfection that the client may expect. This doesn't mean, that everybody working on a job should necessarily know what fee, the company gets for the job. But they should know, what the estimated effort in terms of man power and time is for the job, that are attached to.

If the knowledge workers try to turn a routine job into a research and development effort, management should consider, whether the employees are getting sufficient amounts of professional challenges, and if they do, then if they are the right persons to employ, given the job portfolio of the company. Another commonly found attitude is that young employees continue to approach projects in the same relaxed way, as they did with university assignments. In extreme cases, firing such employees is a strong signal for the remaining ones, but again, if there are no external reasons for reducing staff, it may be better to use internal educational programs to put focus on this issue.

Knowledge workers may be rotated through departments, in order to give them new challenges, and to make them more useful in areas of fluctuating project mass. Further intellectual stimulation may be obtained by occasionally taking an employee out of the productive stream, and let him or her take part in a R&D project, either in the department or at company level. The latter option is important, in case a given department is poor in acquiring projects with an R&D component, or is poor in defining relevant R&D projects within its own area of specialisation. This means that there should be a volume of interdisciplinary or novel area research or development projects carried out at company level, e.g. in a special research department. Precisely how this is to be interpreted naturally depends on the size of the company. In order to serve the purpose mentioned, there should be a fairly large number of R&D projects, rather than a few extended ones. The company may need to develop new areas requiring multiyear R&D efforts, but these projects are not suited for raising the general spirit in the company. Short duration projects, on the other hand, will allow many departments to take part every year, and it may not be so important, if all these projects are successful (for instance by leading to the establishment of new business areas).

Another take-over from the university environment is the phenomenon of judicious assessment of directions received from the management. It orders appear to make sense to the knowledge worker, then fine, but if not, the directive is either ignored or somehow circumvented. The same goes for written material as e.g. the quality manual, the company procedural handbook, the strategy statement, or whatever documents are part of the rule set of a particular company. On one side, it is good that the employees actually reflect on the orders and directives given, but on the other hand, it is intolerable that management is unable to ensure that things are done. There may be cases, where a full explanation of why the management thinks a given instruction is important will help, and explanatory information should generally be given whenever possible (this is more important for knowledge workers than for less educated workers). But, there may be cases where it is not possible or desirable to give the full background for a given instruction to the employees, and where it is still extremely importance that the instruction is obeyed by everyone. It may even make this worse, if the knowledge workers are accustomed to getting explanations with every order, and then don't get it in a particular case.

At the bottom line, this behaviour is again a reflection of a lack of familiarity the business requirements, and perhaps a lack of acceptance of the fact, that a business must be run in a way different from that of an institution of learning. The induction of this fact into new employees is one of the most important challenges for the management of a firm in the knowledge business. They should get the message across in doses of proper size, because it is at variance with the fundamental emphasis on professional pride, and they should do it only in the amounts necessary. If giving orders is used randomly, and also in cases where a full explanation of the "why" would have worked, then the chance of successfully conditioning the employees becomes very small.

A most important tool is, as mentioned, the internal education system of the company. This may consist of informal chats with superiors, but would usually comprise a good deal of formal training, through company educational programmes putting emphasis on the culture of business firms in general and the company in question in particular. The cases used for such courses, and the teachers (usually experienced employees of the company) must be carefully selected, in order to obtain the desired outcome.

The engineer - jack of all trades

People with engineering degrees still constitute the largest group of employees in enterprises operating in the knowledge business. There are features of their education that makes engineers ideally suited for knowledge businesses. To put it short:

The good thing about engineers is that they are trained to think that they can solve any problem. The bad thing is that they sometimes can't!

Looking into the curriculum of engineering schools, this is easy to understand. For a larger company, a good solution is to mix a few non-engineers, either with the deeper natural scientific education of a university, or with relevant social science backgrounds.

(the author spent 3½ years as technical director and board member of a 1500 employee consulting engineering firm)

Interlude 2: Suppose you just need to relax a moment with a poem

POEMS

MEN WITHOUT TITLES

Dictate. Dictate!
Press the button, say
something. Think. Think of saying
something of value.
Something of lasting value.
Ever-lasting value.

Sing, Sing!
Let your heart cry out.
Give your feelings away.
Let it all out.
Words. Words with music.
Song, expression
of supreme impact.
Words and music.
Words in music.
Words song, words
unrecognisable
yet penetrating.
Deep!

Run. Run
like hell, run
your bike, run
your car.
Let the technology of
your passing times
sing its song. BiZarre
to those that come.
Scaring
to those that were.
Run your
vehicle. Speeder down.
FrenZy.
Pollute, king
of the road. Easily
forgotten.

Light.
Let there be
light.
roadlight
floodlight
candlelight
I want to be seen
wanna be your lighthouse
Combust,
make bonfire,
low-energy bulb
halfway disconnected
Save a light
save our lives
save us from polluting fumes
greenhouse gases
signpost
for
the decadence of
ancient civilisation.

Firefly. Firefly,
beat it! I don't wanna
count. I'm through with
nature, rotten
water, urban
civilisation. Count
me out!

=====

Neon, bent,
programmed, bouncing,
running, saying nothing
in technicolor,
neocolor, geocolor, yes
colour!
Water piling up
waves hitting beach
storm and flood
incense and mud.
Civilisations lost.
Waves
gently hitting beach.
You
forever outside reach.

Let me forget it
all, Now!

Fortification.
Walls impeding sight.
Soldiers, invisible,
just a dream.
Nightmare come true.
Again and again.
History of Earth.
Will it never stop.
Empires
rise
fall
decay
fall apart.
Blood all over.
Again and again.
Progress, civilisations.
Will it never stop?
Shoot, shoot
Here we go again.
Did you
remember friendship,
companions from all over.
Did you
forget love
?

BLANK SPACE

(put your own thoughts)

(extinct animal)

REFERENCES

Anthony, P. (1977). *The Ideology of Work*, Tavistock Publications, London

Barnaby. F. (1981). Bulletin of the Atomic Scientists, June, pp. 11-12

Beyer, K.. S. Blegaa, B. Olsen, J. Reich and M. Vedelsby (1983). Girls and Physics. IMFUFA Text No. 71. Roskilde University (in Danish)

Bohr. N. (1950). Open Letter to the United Nations. Schultz Publ. Co., Copenhagen

Bonke, J. (1983). *Never again work***.** Rosinante Publishers, Copenhagen (In Danish)

Boston Study Group (1979). *The Price of Defense.* Times Books, New York

Cai Zu-quan (1974). Wuli Xuebao. vol. 23, No. 3. pp. 153-154 (English translation: Chin. J. Phys., vol. 23. No. 3, pp. 93-94)

Carson. R. (1962). *Silent Spring*. Fawcett Crest, New York

Clement, J. (1982). American Journal of Physics, vol. 44, p. 834

Danmarks Statistik (1980). Living Conditions in Denmark. Published in conjunction with Danish National Institute of Social Research, Copenhagen

Danmarks Statistik (1983). Statistiske Efterretninger. Education and Culture, No. 3

Dickson, D. (1974). *Alternative Technology*, Fontana Press**,** London

Diesendorf, M. (1982). Science under Social and Political Pressures. In *Science and Ethics* (D. Oldroyd, ed.). New South Wales Univ. Press, pp.48-73; Sounding the Alarms: The Dilemma of the Scientific Expert. In *Focus on Social Responsability in Science* (W. Green, Ed.), pp. 61-83. New Zealand Association of Scientists. Inc., Wellington

Dyson, F. (1981). *Disturbing the Universe*. Harper Colophon Books. New York

Ellinger. H. (1897). *Nature and its Forces.* Popular Physics. The Nordic Publishing Co., Copenhagen (in Danish)

Elliott. D. and R. Elliott (1976). *The Control of Technology*. Wykeham Publ. Co., London

Falk, J. (1982). *Global Fission*. Oxford University Press, Melbourne

Feynman, R. (1973). Feynman on Physics (interview), GAMMA No. 16, pp. 22-28. The Niels Bohr Institute, Copenhagen (Danish translation)

Forbes. I. D. Ford. H. Kendall and J. MacKenzie (1971). Nuclear News. September, pp. 32-40

Ford, D., H. Kendall and J. MacKenzie (1972). Nuclear News, January, pp. 28-35

Forrester, J. (1971). *World Dynamics*, Wright-Allen Press, Massachusetts; Meadows, D. & D, Randers, J. and Behrens, W. (1972). *The Limits to Growth*, Universe Books, New York

Hansen. S. (1981). In Politiken, October 19. (Newspaper article)

Hsu Hsiang-Chlen (1978). Hongqi No. 8 (English translation in China Today, No. 32, August 11, 1978)

Illich, I. (1971). *Celebration of Awareness*. Calder & Boyars, London

Kelly, A. (1978). *Girls and Science*. Almquist & Wiksell, Stockholm; see also A. Kelly (ed.) (1981). *The Missing Half: Girls and Science Education*. Manchester University Press

Kitaigorodsky. A. (1971). *I am a physicist*. Mir Publishers, Moscow

Jensen. F. and O. Winther (1980). *Distribution of Junior College grades on sex and social origin*. Aalborg University Center, Report No. R80-3 (in Danish)

Jungbluth. P. (1982). *Teachers over the education of girls*. Nijmegen Institute for Applied Sociology (as quoted by Nielsen. L. (1983). LMFK No. 4. pp. 9-13. in Danish)

Jungk. R. (1963). *Brighter than Thousand Suns*. Scherz Publishers, Bern; see also R. Moore (1966). *Niels Bohr, The Man, His Science, and the World they Changed*. Alfred Knopf, New York (pp. 258-261)

Lempert. R. (1981). Bulletin of the Atomic Scientists, January, pp. 61-64

Lewis. H., R. Budnitz, H. Kouts. W. Loewenstein. W. Rose, F. von Hippel and F. Zachariasen (1978). U.S. Nuclear Regulatory Commission Report NUREG/CR-0400. Washington D.C.; Sørensen, B. (1979). Ambio, vol. 8, pp. 10-17

Lie. S. and S. Sjoberg (1981). *Speed and Force*. Physics Institute of Oslo University (In Norwegian); Repeated in Denmark in 1982, cf. Nielsen and Thomsen (1983)

Linder, S. (1970). *The harried leisure class*. Columbia University Press, New York

Lundberg. B. (1965). Bulletin of the Atomic Scientists. February, pp. 29-33

Maccoby. E. and C. Jacklin (1974). *The Psychology of Sex Differences*. Stanford University Press. Rebuttal in Fennema, E. and J. Sherman (1977). American Educational Research Journal, Vol. 14, pp. 51-72

Magraw, K., and J. Isaacs (1983). Bulletin of the Atomic Scientists. April, p. 29

Mamontov. V. (1979). *Disarmament - the Command of the Times*. Progress Publishers, Moscow

Martin. B. (1979). *The Bias of Science*. Society for Social Responsability in Science, Canberra

Mattuck, D. (1981). *Common law of Physics*. Politiken. March 14. (Danish newspaper)

McCloskey et al. (1980). Science, vol. 210. pp. 1139-1141

Mishan, E. (1969). *Growth. The Price we pay*. Staples Press, England

National Academy of Sciences (1972). *Physics in Perspective*. Volume I. Washington D.C.

Nielsen, H and P. Thomson (1983). Junior College Physics Report Nos. 1 and 2. Physics Institute of Aarhus University (In Danish)

Norman. C. (1982). Science, vol. 215. p. 377

Pedersen, A. and I. Frimodt-Møller (1983). Girls in Junior College - Survival or Liberation. Emmeline Publishers, Copenhagen (In Danish)

Porat, M. (1977). *The Information Economy (5* vols.). U.S. Department of Commerce. Washington D.C.

Primack, J. and F. von Hippel (1974). *Advice and Dissent*. Basic Books, New York

Rasmussen. N. (1972). Nuclear News, January, pp. 35-40

Røn, L., S. Stender, L. Pedersen and L. Eilertzen (1982). *Girls and Mathematics*. IMFUFA Text No. 51. Roskilde University Center (in Danish)

Sayre, A. (1975). *Rosalind Franklin and DNA*. Norton & Co., New York

Saxe. R. and Murray, R. (P.Unch and J.Udy) (1972). Nuclear News. January, pp. 69-70

Schumacher, E. (1973). *Small is Beautiful*, Blond & Briggs, London

Scott, J. (1982). *Scientific American*, September, pp. 137-151

Shurcliff, W. (1970). *SST/Sonic Boom Handbook*. Ballantine Publishers. New York

SIPRI (1981). *Yearbook*. Stockholm International Peace Research Institute, Stockholm

Sivard, R. (1980). *World Military and Social Expenditures*, World Priorities Inc., Leesburg

Strassmann, S. (1979). *Technology Review*, vol. 82, Dec. 1979/Jan. 1980, pp. 54-65

Sørensen, B. (1984). Energy planning draft, later appearing as part of Chapter 6 *in Renewable Energy*, *2nd edition*, Academic Press, London and San Diego, 2000; also Crossley, D. and Sørensen, B., *Creating Energy Futures: a short guide to energy planning*, IMFUFA Texts No. 63 (1983), Roskilde University

Thee. M. (ed.) (1976). *Armaments and Disarmament in the Nuclear Age*. The MIT Press, Cambridge

Ullrich, O. (1979). *In the blind alley of the industrial system*, Rotbuch, Berlin (in German)

United Nations General Assembly (1981). Report No. A/36/356

United States Nuclear Regulatory Commission (1975). *Reactor Safety Study*, Report WASH-1400/NUREG 75/014. Washington D.C.

U.S. Department of Commerce (1975). *Historical Statistics of the United States, Colonial Times to 1970* Part 2, Washington D.C.

U.S. Department of Commerce (1981). *Statistical Abstracts of the United States*, Washington D.C.

U.S. National Academy of Sciences (1972). *Physics in Perspective* Vol. 1, Washington D.C.

Valaskakis, K. and Fitzpatrick-Martin, I. (1980). "Socio-political Impacts of the Information Economy", in *The Human Context for Science and Technology* (T. Schrecker and C. Hooker, Eds.). Research Council of Ottawa, Canada

Watson. J. (1968). *The Double Helix*. Atheneum, New York

Weisskopf, V. (1980). The Bulletin of the Atomic Scientists, April, pp. 17-21